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Evaluation of Triple Simultaneous Parallel ILS Approaches Spaced 4300 Feet Apart, Final Monitor Aid with Simulated Radar 4.8 Second Update Rate
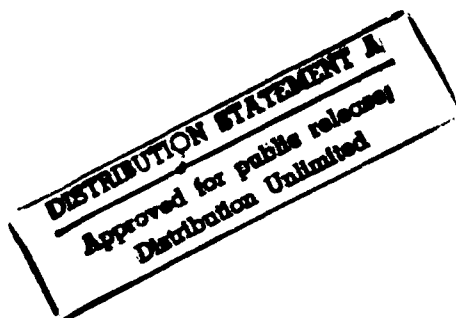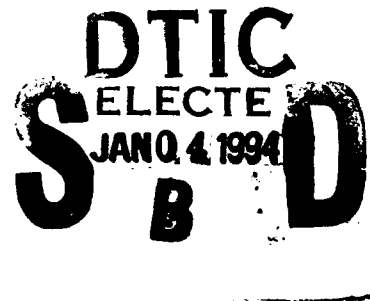
Volume I

ATC Simulation Team
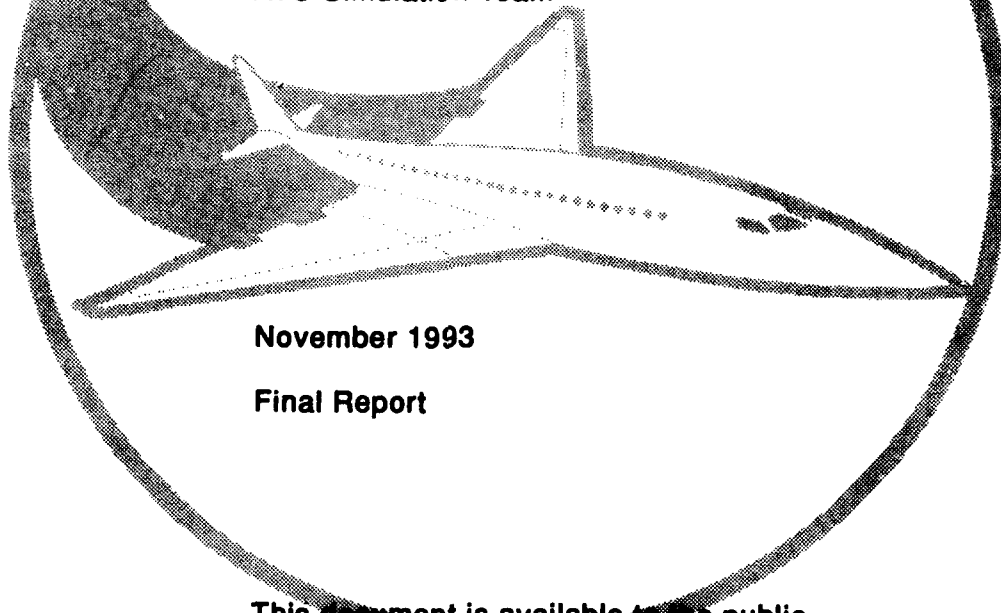
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16. Abstract

This study evaluated the ability of controllers to monitor approach traffic during instrument meteorological conditions using a real-time, interactive, air traffic control simulation. The airport configuration consisted of triple parallel runways spaced 4300 feet apart with even thresholds and a field elevation of 600 feet. A radar system with a 4.8 second update rate and 2 milliradian accuracy was simulated. Controllers used Final Monitor Aid displays. Use of the term "Break" as a replacement for "Immediately" during a blunder situation was also tested.

The simulation measured controller performance by analyzing the smallest slant range miss distance, closest point of approach, between blundering aircraft and evading aircraft. Data were also collected concerning aircraft No Transgression Zone entries as well as false breakouts.

Controller and pilot questionnaire responses indicated that the use of the term "Break" was unnecessary. The Multiple Parallel Approach Program Technical Work Group and the participating controllers concluded that the simulated approach operation would be safe and viable using current technology radar sensors and the Final Monitor Aid displays.

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EXECUTIVE SUMMARY

This study is part of an on-going effort to evaluate plans for increasing air traffic capacity and to evaluate the feasibility of using multiple simultaneous parallel Instrument Landing System (ILS) approaches. The objective of this study was to evaluate the ability of controllers who were experienced with multiple parallel approach operations to handle approach traffic during Instrument Meteorological Conditions (IMC) to a proposed triple parallel runway airport configuration, using a real-time, interactive, air traffic control (ATC) simulation. It should be kept in mind that, like the output of all experimental evaluations, the results of this study should not be extrapolated to situations which contain variables other than those tested in this study.

The proposed configuration consisted of triple parallel runways spaced 4300 feet (ft) apart. The generic airport had a field elevation of 600 ft. A radar system with a 4.8 second (s) update rate and 2 milliradian accuracy was simulated. The Final Monitor Aid (FMA) (high resolution color display equipped with the controller alert system hardware/software used in the precision runway monitor system) was used for the final approach monitor position. The air traffic consisted of both flight simulators and computer-generated aircraft which emulated turbojets, turboprops, and propeller driven aircraft.

Simultaneous parallel ILS approaches were simulated with controllers monitoring traffic on the final approach localizers. To challenge the system, scenarios were developed to create conflicts between aircraft. Blunders were generated by having some of the simulated aircraft deviate from the localizer by either 20 or 30 degrees. Furthermore, 70 percent of the blundering aircraft simulated a total loss of radio communication (NORDO) with the controllers. This simulation also tested the effectiveness of the word "BREAK" as a replacement for the word "IMMEDIATELY," when urgent instructions were issued during a blunder situation.

The central issue in the study was the ability of the controllers to maintain distance between a blundering aircraft and aircraft on adjacent parallel approaches. Two questions were addressed:

1. Would the controllers be able to maintain the test criterion miss distance of 500 ft between aircraft?

2. Do the controllers, technical observers, the Multiple Parallel Technical Work Group (TWG), and other Federal Aviation Administration (FAA) management observers agree that the operation of this proposed triple simultaneous parallel ILS approaches is acceptable, achievable, and safe as simulated?

The results indicated that controllers were able to resolve 99.7 percent of the conflicts in the simulation. Of the 290 conflicts, only one conflict resulted in aircraft violating the criterion miss distance of 500 ft. The controllers stated that the FMA enabled them to effectively resolve blunders. They concluded that triple simultaneous parallel ILS approaches with runway centerlines spaced 4300 ft apart would be a "safe and viable operation" using current technology radar systems and the FMA.

In response to the Airline Pilots Association's (ALPA) request to use the term "BREAK" in the evasive maneuver instead of the term "IMMEDIATELY," six of eight controllers did not like the use of the term "BREAK." One controller thought the term was unnecessary. The controllers believed the use of the term "BREAK" in simultaneous approaches would be uncharacteristic for its normal definition in controller phraseology. The majority of the pilots also agreed the term "BREAK" would not be a practical replacement for the term "IMMEDIATELY." Their reasoning was the term "BREAK" is already used by controllers to indicate a break in communications, therefore, the additional meaning of the term "BREAK" may result in confusion.

Total system error (TSE) is the difference between the path the aircraft flies and the intended path. This may be expressed as a statistical combination of all sources of navigation error including navigation signal source, propagation, airborne system, and flight technical error (FTE). For this simulation, TSE was evaluated with two measures: frequency of No Transgression Zone (NTZ) entries that were not the result of a blunder or a breakout, and percentage of false breakouts.

Of the 486 approaches flown by flight simulators, there were 18 (3.7 percent) NTZ entries. Of the 2374 triple approaches flown by computer-generated aircraft, there were 30 (1.0 percent) NTZ entries. False breakouts occurred when an aircraft was vectored off an approach for reasons other than a conflict. False breakouts occurred with 127 (4.4 percent) of all aircraft that were not involved in a blunder.

The TWG, comprised of individuals from the Office of System Capacity and Requirements, Air Traffic, Flight Standards, Aviation System Standards and Operations personnel, participated in the simulation and evaluated the simulation findings. Based upon the TWG's understanding of daily air traffic operations, the knowledge and skills of controllers, and the contingencies that must be accounted for, the TWG determined that the triple simultaneous parallel ILS approach operation spaced at 4300 ft is acceptable using the FMA and the simulated airport surveillance radar (ASR) system with a 4.8 s update rate.

1. OBJECTIVE.

The Federal Aviation Administration (FAA) and the Multiple Parallel Technical Work Group (TWG) are evaluating the capability of multiple parallel runways to increase airport capacity in a safe and acceptable manner. The goal is to develop national standards for using multiple simultaneous parallel Instrument Landing System (ILS) approaches with both existing and/or new technology equipment.

The objective of this study was to evaluate the ability of air traffic controllers to handle traffic while monitoring triple simultaneous parallel ILS approaches with runways spaced 4300 feet (ft) apart. A real-time air traffic control (ATC) simulation evaluated controller performance using the Final Monitor Aid (FMA) (high resolution color display equipped with the controller alert system hardware/software that is used in the Precision Runway Monitor (PRM) system) and a simulated radar with a 4.8 second (s) update rate. The results of this study will be used toward the establishment of national standards for triple simultaneous parallel ILS approaches.

2. BACKGROUND.

The ability of the National Airspace System (NAS) to meet future air traffic demands is a serious concern at the national level. Programs to improve NAS capacity have been underway since the early 1980's, both to reduce air traffic delays and to accommodate the increased demand. The programs' objectives are to redesign the existing airways structure, provide a more modern air traffic flow management capability, and incorporate state-of-the-art automation technology throughout the system.

The procedures currently allow for dual simultaneous ILS approaches in instrument meteorological conditions (IMC) only to runways spaced not less than 4300 ft apart with existing equipment. A simulation was conducted that evaluated 4300 ft triple simultaneous parallel ILS approaches using a simulated radar system with a 4.8 s update rate and Automated Radar Terminal System (ARTS) IIIA displays (CTA, 1991). The results from this simulation indicated that triple simultaneous parallel ILS approach operations spaced 4300 ft apart were not acceptable using existing equipment as simulated.

The results of the simulation also indicated that controllers were not able to detect aircraft course deviations early enough to implement conflict resolution strategies. It was believed, however, that high-resolution color displays and controller alerts could provide controllers with the lead time necessary to implement conflict resolution strategies. Consequently, this study was developed to evaluate triple simultaneous parallel ILS

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approaches to runways spaced 4300 ft apart using the FMA and current radar systems with a 4.8 s update rate.

2.1 CURRENT SIMULTANEOUS APPROACH PROCEDURES.

The number of aircraft that can land at an airport during IMC is a major factor influencing system capacity. An increase in the number of simultaneous ILS approaches would significantly increase airport capacity during IMC and potentially improve traffic flow throughout the NAS.

Contributing to the capacity problem are the limitations imposed by current airport runway configurations and the associated air traffic separation criteria, particularly as related to aircraft executing ILS approaches under IMC. To alleviate these constraints, the FAA is investigating the use of triple, quadruple, and closely spaced dual parallel runway configurations as a means of increasing airport capacity, while maintaining the high level of safety evident today.

At the time this study was conducted, simultaneous approaches to parallel runways in IMC were limited to two approaches, and only when runways were spaced not less than 4300 ft apart. Approaches to runways spaced less than 4300 ft were restricted in IMC due to limitations in current radar and displays. Under such circumstances, ATC must use dependently sequenced approaches.

The procedures currently required for dual simultaneous ILS approaches are described by FAA Order 7110.65G, paragraph 5-126 as follows:

    a. Parallel runways that are at least 4300 ft apart.

    b. Straight-in landings will be made.

    c. Provide a minimum of 1000 ft vertical or a minimum distance of 3 nautical miles (nmi) between aircraft during turn-on to parallel final approaches.

    d. Provide the minimum applicable radar separation between aircraft on the same final approach course.

    e. Aircraft established on final approach course are considered separated from aircraft established on an adjacent parallel final approach course provided neither aircraft penetrates the No Transgression Zone (NTZ).

    f. Separate monitor controllers, each with transmit/receive and override capability on the local control frequency, shall ensure aircraft do not penetrate the depicted NTZ.

In addition, paragraph 5-127 authorizes simultaneous independent ILS approaches to parallel runways spaced 3400 to 4300 ft apart with the caveat that PRM's and a radar update rate of 2.4 s or less be used. The modification to the requirement was the result of research conducted at the Raleigh/Durham and Memphis Airports (Precision Runway Monitor Program Office, 1991). The research indicated that through improvements in radar sensors and displays, the minimum runway spacing requirement could be reduced while maintaining the current level of safety. Reducing the minimum runway spacing requirement permits current airports to be modified rather than new airports being built.

2.2 PREVIOUS PARALLEL RUNWAY STUDIES.

Early studies of multiple runways concentrated on reducing separation between aircraft during simultaneous parallel approaches. These studies have indicated that the reduction of separation between aircraft is dependent upon many factors, including pilot/aircraft navigational accuracy, radar update rate, radar accuracy, and controller displays.

A simulation conducted in 1984 investigated runway spacing, modified radar displays, improved radar accuracy, and higher update rate radar (Buckanin, D., et al., 1984). The study established the importance of navigational accuracy in determining system capacity and showed the relationships between a number of system parameters and the controllers' abilities to cope with blunders.

Since the study in 1984, aircraft navigation data have been collected at the Memphis International Airport and at the Chicago O'Hare Airport (Buckanin, D., and Biedrzycki, R., 1987; Timoteo, B. and Thomas, J., 1989). These studies considered simultaneous parallel approaches under IMC. Data generated from these studies were used in the development of the navigational model for the present simulation.

Additional real-time ATC simulations have been conducted by the Precision Runway Monitor Demonstration Program (Precision Runway Monitor Program Office, 1991) and the Multiple Parallel Approach Program. These studies are an important complement to the models cited since they generated estimates of the model parameters and, more importantly, they allowed direct observation and recording of criterion measures related to safety and capacity.

2.2.1 Precision Runway Monitor Demonstration Program.

The Precision Runway Monitor Demonstration Program conducted real-time simulations to test the PRM system (high resolution controller displays in conjunction with improved radar sensors) and to determine if the PRM system would allow for reduced runway separation while maintaining the current level of safety

(Precision Runway Monitor Program Office, 1991). High resolution displays with controller alerts were installed at Raleigh/Durham, NC, with an E-Scan Radar System (1.0 s update rate), and Memphis, TN, with a Mode S Back-to-Back Radar System (2.4 s update rate).

The study evaluated the standard for runway separation during independent simultaneous approaches (4300 ft) and reduced the runway separation to 3400 ft using the high resolution displays with controller alerts. The study concluded that the high resolution displays with controller alerts and either the E-Scan Radar System or the Mode S Back-to-Back Radar System could be used to effectively monitor parallel runways spaced 3400 ft apart. The results of this report were used as the basis for the recent modification in the simultaneous ILS approach requirements.

2.2.2 Multiple Parallel Approach Program.

This study is part of the Multiple Parallel Approach Program which is evaluating various runway spacings and air traffic equipment using real-time simulations. The program began in 1988 to evaluate simultaneous approaches at the Dallas/Fort Worth (DFW) Airport. After the completion of three studies on the DFW configuration, the thrust of the studies shifted to developing national standards for multiple simultaneous approaches.

The Multiple Parallel Approach Program consists of six phases. An overview of the parameters of the simulations and the results of the phases can be seen in figure 1. Each phase of the Multiple Parallel Approach Program is described in appendix A.

3. ATC STANDARDS MODIFICATION REQUIREMENTS.

The absolute requirement for modifying ATC standard procedures is the demonstration of undiminished safety. Evidence supporting safety as a result of proposed system changes can be obtained in a number of ways:

a. Demonstrate, through the collection and analysis of operational data, that new or improved standards can be developed.

b. Conduct flight tests proving the feasibility and safety of proposed changes.

c. Conduct operations research, mathematical modeling, or fast-time simulation, and examine the impact of proposed changes on a variety of operational parameters and contingencies.

d. Conduct real-time ATC simulation studies while introducing errors and failures to assess system performance.

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Phase	Dates	Purpose	Approach	Runway Spacing	Display	Simulated Radar	Other
I	5/16-6/10 88	DFW	Quadruple	5000 & 5800 ft 8800 ft	SANDERS/ DEDS	ASR-9 4.8s	
II	9/25-10/5 89	DFW	Triple	5000 & 8800 ft	SANDERS/ DEDS	ASR-9 4.8s	
III	11/29-2/9 90	DFW	Dual and Quadruple	5000 & 5800 ft 8800 ft	SANDERS/ DEDS	ASR-9 4.8s	
IV.a	4/24-5/3 90	National Standards	Triple	4300 ft	ARTS III	ASR-9 4.8s	
IV.b	9/17-9/28 90	National Standards	Triple	5000 ft	ARTS III	ASR-9 4.8s	
V.a.1	5/15-5/24 91	National Standards	Dual and Triple	4300 ft	FMA	ASR-9 4.8s	
V.a.2	9/24-10/4 91	National Standards	Triple	4000 ft	FMA	ASR-9 4.8s	
V.a.2.2	7/27-8/14 92	National Standards	Dual and Triple	4000 ft	FMA	ASR-9 4.8 s	
V.b.1 & V.b.2	3/18-4/5 91	National Standards	Dual and Triple	3000 ft	FMA	E-Scan 1.0s	
V.b.3	9/16-9/23 91	National Standards	Dual	3000 ft	FMA	E-Scan 1.0s	1-Degree Localizer Offset
V.c	5/6-5/14 91	National Standards	Triple	3400 ft	FMA	Mode S 2.4 s	
V.d	3/2-3/13 92	Human Factors Study	Triple	3400 ft	FMA	E-Scan 1.0 s	1 Mr Radar Accuracy
V.a.2.2	7/27-8/14 92	National Standards	Triple	4000 ft	FMA	ASR-9 4.8 s	
n/a	9/8-9/25 92	Density Altitude Study	Triple and Quadruple	7600 ft 5280 ft 5348 ft	ARTS III	ASR-9 4.8 s	Field Elevation 5431 ft
n/a	11/16-11/20 92 11/30-12/17 92	DIA	Triple	7600 ft 5280 ft	FDADS FMA	ASR-9 4.8 s	Field Elevation 5431 ft

FIGURE 1. MULTIPLE PARALLEL APPROACH PROGRAM SIMULATIONS

These approaches are neither independent nor mutually exclusive. Reliable field data are essential for successful modeling and simulation operations. Real-time ATC simulation, flight simulation, and flight testing are needed to generate estimates of the operational parameters used for modeling and fast-time simulation. Modeling provides a framework for collecting and analyzing field data.

The desire to provide absolute certainty in the outcome of an extremely rare event may reduce system capacity below acceptable limits. Ultimately, the decision falls upon the experienced system users (e.g., controllers, pilots, and operations personnel) to weigh the evidence and decide upon the proposed configurations. The users base their decisions on: (1) their understanding of daily operations, (2) the knowledge and skills of air traffic controllers, and (3) the contingencies to which the system must respond.

4. PHASE V.a.1 EVALUATION OF TRIPLE SIMULTANEOUS PARALLEL ILS APPROACHES SPACED 4300 FT APART.

This section describes the simulation performed May 15 - 24, 1991. An overview of the simulation, the simulation operations, the simulation procedures, and the data collection methods used in the analyses are presented in sections 4.1 through 4.4. The simulation assessment methodology is presented in section 4.5.

4.1 SIMULATION OVERVIEW.

Phase V.a.1 evaluated simultaneous ILS approaches to triple parallel runways spaced 4300 ft with even thresholds. The simulation was designed to examine operational issues relative to the development of national standards for the implementation of triple simultaneous parallel ILS approaches.

The final approach monitor positions were manned by controllers who were experienced with multiple parallel approach operations to ensure that traffic movement was in accordance with established procedures. Some of the aircraft making the final approach were scripted to execute blunders of 20 or 30 degrees toward an aircraft on an adjacent approach. The controllers issued instructions, via voice communications, to the pilots in order to maintain adequate separation between aircraft at all times. The simulation addressed two questions:

a. Can the controllers prevent conflicts from resulting in a miss distance of less than the test criterion (500 ft)? Simply stated, can the controllers issue corrective actions so that a blunder does not result in a test criterion violation (TCV)?

b. Do the controllers, technical observers, the TWG, and other FAA management observers view the triple approach operation as acceptable, achievable, and safe as simulated?

4.1.1 Airport Configuration.

The airport layout, runways, and arrival frequencies emulated a generic airport with a field elevation of 600 ft, even thresholds, and glide slopes of 3 degrees. The distance between the runway centerlines was 4300 ft, and the length of the runways were 10,000 ft to accommodate all aircraft types.

The airport configuration consisted of 3 parallel runways with an arrival heading of 180 degrees (18R, 18C, and 18L) as shown in figure 2. A mix of aircraft types started on the localizer and maintained their turn-on altitude until intercepting the glide slope. The starting altitude and glide slope intercept for each runway is provided in table 1. After glide slope intercept, the aircraft commenced at a normal rate of descent appropriate for the aircraft type being simulated.

4.1.2 Controllers.

Six air traffic control specialists from different Terminal Radar Approach Control (TRACON) facilities (Atlanta, Dallas/Fort Worth, Denver, Minneapolis, Pittsburgh, and Sacramento) participated in the simulation. All of the controllers were volunteers selected in agreement with their National Air Traffic Controllers Association offices. The selected controllers participated in the Phase IV and the Phase V.b simulations and were experienced with simultaneous parallel approach operations.

Controller assignments are shown in appendix B. Randomization of participant scheduling was carried out with the following restrictions:

a. Individual controller participation was limited to 1 hour per run. Controllers participated in not more than 2 consecutive hours per day and a total of not more than 3 hours per day as a monitor controller.

b. Controller assignments were balanced throughout the day.

c. Individual controller assignments were equally divided with respect to runways.

4.1.3 Blunders.

Blunders were used to test the controllers' ability to maintain adequate distances between aircraft during critical situations. They were created by instructing an aircraft to deviate 20 or 30 degrees from the ILS toward an aircraft on an adjacent runway.

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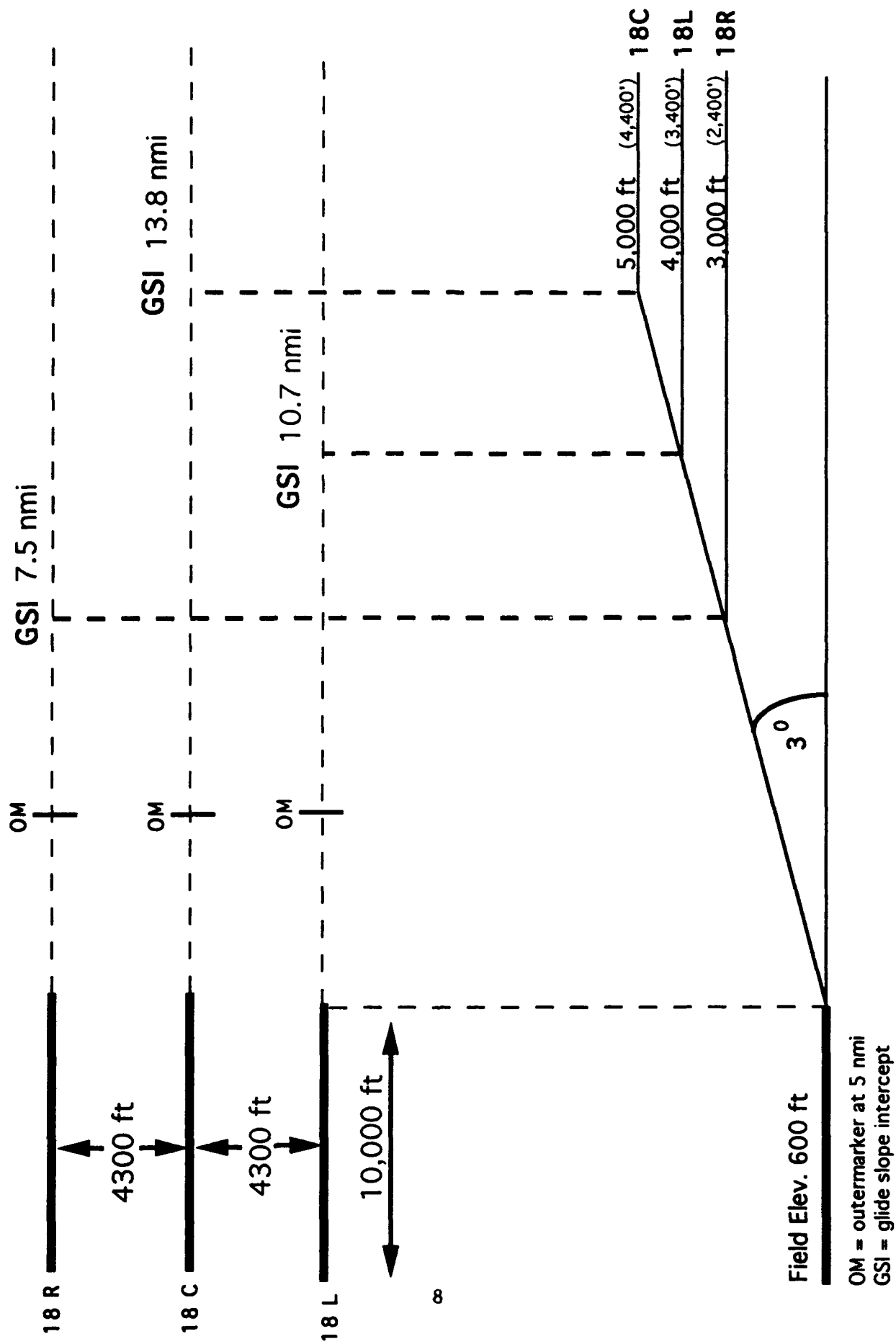
FIGURE 2. AIRPORT CONFIGURATION

The deviation off of the ILS usually resulted in a conflict between two aircraft. The controllers issued instructions to the pilots to either rejoin the localizer, or change heading or altitude in order to resolve the conflict.

TABLE 1.   PHASE V.a.1 ILS RUNWAY TURN-ON ALTITUDES

Runway	Turn-On Altitude (ft)	Glide Slope Intercept (nmi)
18R	3000	7.5
18C	5000	13.8
18L	4000	10.7

4.2   SIMULATION OPERATIONS.

The simulation was conducted in the NAS Simulation Support Facility (NSSF) at the FAA Technical Center, Atlantic City International Airport, NJ.   The NSSF is comprised of a multitude of networks and computer systems which generated the ATC ground parameters and integrated the controllers, flight simulators, and computer-generated aircraft into the simulation.   A schematic overview of the operations of the NSSF is shown in figure 3.

4.2.1   Computer System and Controller Monitors.

Three controller monitors each with their own computer system were located in the NSSF Laboratory.   Each station consisted of a 20 X 20 inch, high-resolution (2048-line by 2048-pixel) color monitor which utilized raster scan technology.   The graphics for the monitors were generated by a Metheus graphics driver, and the operating system was driven by a micro-VAX computer.

The displays had numerous features which enhanced the controllers' ability to detect blunders and control the airspace. These features included color coding, scalable display parameters, aircraft predictor lines, and audio and visual warnings.

The features of the airport configuration were depicted in different colors for easy identification.   For example, the ILS was displayed as white dashed lines, the NTZ was outlined in red, and the 200-ft deviation lines were designated in blue.

The scaling of the horizontal and vertical axes of the display could be modified to improve the detection of aircraft movement between runways.   For this simulation, the ratio of magnification

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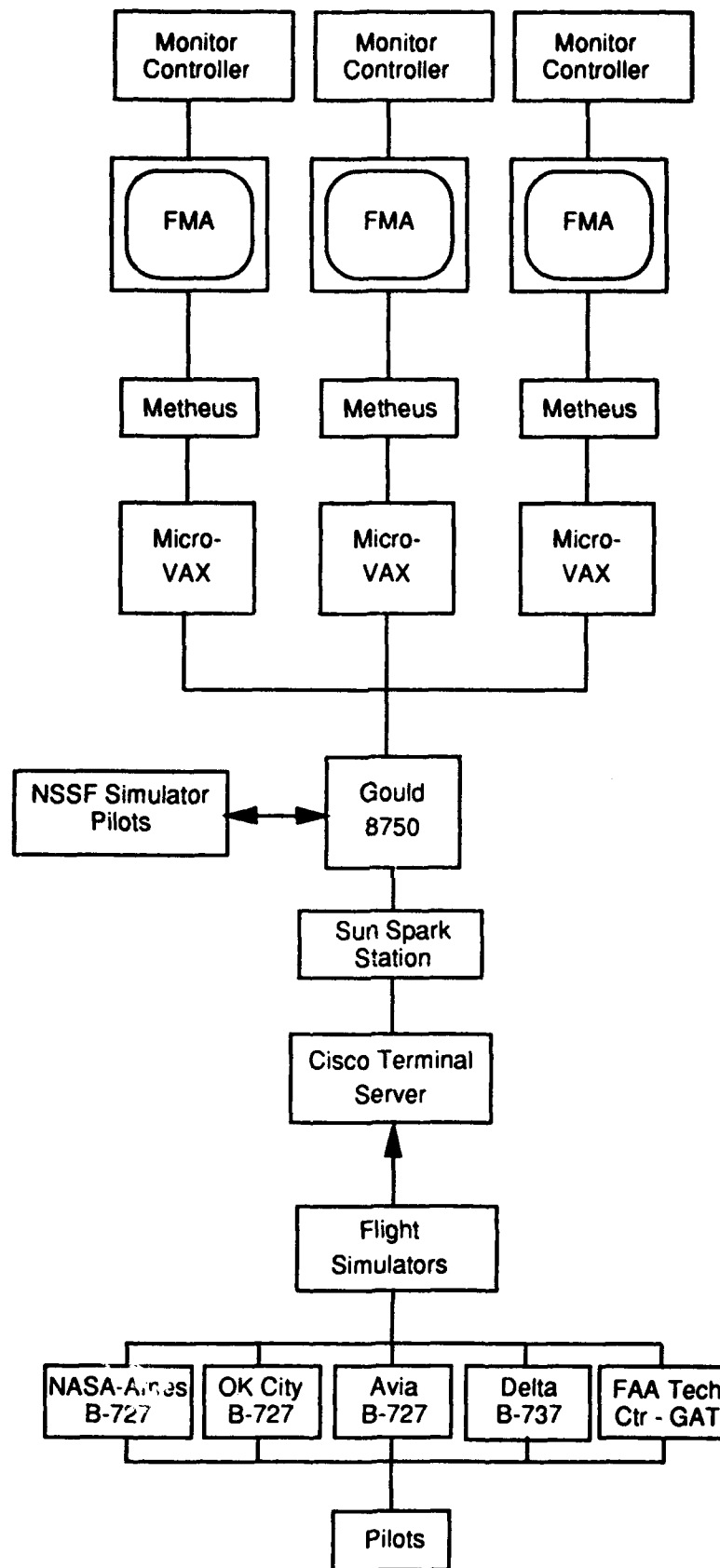
FIGURE 1.   SCHEMATIC DIAGRAM OF NSSF CONFIGURATION

was set to 1.8 for the vertical axis and 8.0 for the horizontal axis. The axes remained constant throughout the simulation.

A predictor line, which was affixed to each aircraft target, indicated where the aircraft would be in 10 s if it continued on the same path. The predictor line provided the controller with advance notice of the path of the aircraft. The length of time for the advance notice by the predictor line could be varied, but for this simulation it was set to 10 s.

The predictor line was also used in the generation of the audio and visual alerts. When the predictor line indicated that an aircraft was within 10 s of entering the NTZ, an audio alert sounded "Warning" and the call sign of the aircraft which was straying off of the ILS. Visually, the aircraft target and data block changed color from green to yellow. If the aircraft entered the NTZ, the aircraft target and data block turned red.

4.2.2 Radar System.

The simulated radar system had an azimuthal accuracy of 2.0 milliradians and a 4.8 s update rate. This radar system is currently being used in high capacity airports where simultaneous ILS approaches are being conducted.

4.2.3 Traffic Samples.

Traffic samples were based on actual air traffic from a combination of numerous high density airports (e.g., Atlanta, Chicago, DFW, Denver, Los Angeles, and other TRACON's) and consisted of representative aircraft types and identifiers.

Eight traffic samples were developed for the simulation. Aircraft start times were controlled to produce traffic samples in which the minimum in-trail separation distance (3 nmi) was maintained while producing maximum through-put. The traffic samples also contained a variety of aircraft speeds (120 to 185 knots). This created two to three speed overtakes per run.

The air traffic was comprised of both flight simulators and computer-generated aircraft. In conflict situations, the blundering aircraft were always computer-generated aircraft, while the majority of the evading aircraft were flight simulators.

4.2.3.1 Flight Simulators.

Five flight simulators were integrated into the simulated airspace to generate realistic air tracks and pilot response times. Three of the flight simulators were B-727's and were provided by NASA-Ames, Moffett Field, CA; FAA Mike Monroney Aeronautical Center, Oklahoma City, OK; and AVIA, Inc., Costa

Mesa, CA. A B-737 Flight Simulator was provided by Delta Air Lines, Inc., Atlanta, GA, and a General Aviation Trainer (GAT) was provided by the FAA Technical Center, Atlantic City International Airport, NJ.

Flight simulators were flown by current air carrier and air taxi pilots. The flight simulators were programmed to assume the configuration of aircraft flying the localizer course and replaced computer-generated aircraft that were scheduled to enter the simulation. In addition, pilots were required to execute 30-degree localizer intercepts. Intercept occurred approximately 17 nmi prior to touchdown. At the pilots' discretion, approaches were flown utilizing either autopilot, flight director, and/or raw data.

To provide additional realism, a crosswind condition was introduced during the flight simulator approaches. The wind conditions were balanced throughout the simulation such that one-third of the runs had simulated winds from the east, one-third of the runs had simulated winds from the west, and one-third of the runs had no wind condition simulated. After the final approach fix, but prior to approximately 1000 ft above ground level, the wind was proportionately reduced to arrive at a crosswind component not to exceed 10 knots at the runway threshold. Additionally, to maintain proper longitudinal spacing between flight simulator targets and computer-generated aircraft, a headwind or a tailwind component was introduced to adjust flight simulator speeds after turn-on to final.

The flight simulator pilots were in voice communication with the controllers in the NSSF Laboratory at the FAA Technical Center. There was also a coordinator assigned to each site to provide the pilots with the appropriate flight information and to debrief the pilots. Each flight simulator flew approximately 10 approaches per simulation run.

4.2.3.2 Computer-Generated Aircraft.

Computer-generated aircraft were used to increase the volume of traffic and to initiate blunders. Normal aircraft cross track deviations for the computer-generated aircraft tracks were generated by a navigational error model executed by the Gould computer. The navigational error model was based on data collected at Chicago O'Hare (Timoteo, B. and Thomas, J., 1989). A detailed description of the navigational error model can be found in appendix C.

A facility, separate from the controllers, contained the personnel who operated the computer-generated aircraft. These NSSF aircraft operators were in voice contact with the controllers and entered changes in aircraft heading or altitude using a specialized keyboard. These actions resulted in the

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simulated aircraft being taken off of the localizer and flying the course entered by the NSSF aircraft operator. The simulated aircraft responses were programmed to be consistent with the type of aircraft being simulated. Each NSSF aircraft operator had the ability to control as many as 10 aircraft, but typically controlled less than 3 at one time during this simulation.

4.2.4 Tower Controllers.

Tower controller positions were implemented into the ATC environment to provide realism on the communication frequencies. The tower control positions were manned by controllers who were not scheduled to participate in that run.

4.3 SIMULATION PROCEDURES.

The simulation was conducted May 15 - 24, 1991. Three 2-hour runs were performed each day. A total of 22 runs were completed during the simulation.

4.3.1 Blunder Scripts.

Blunder scripts were used to create conflict situations between aircraft. To create a blunder, the test director instructed an NSSF aircraft operator to deviate the heading of a computer-generated aircraft 20 or 30 degrees from the ILS toward an aircraft on an adjacent approach. Only 30-degree blunders were implemented when a flight simulator would be affected by a blunder. The deviation off of the ILS usually resulted in a conflict between two aircraft. The controllers issued instructions to the pilots to either rejoin the localizer, or change heading or altitude in order to resolve the conflict.

Blunders were scripted in order to control the frequency and the severity of the conflicts. Furthermore, the paths of the blundering aircraft were scripted so that the aircraft either maintained altitude or continued to descend during the blunder. Blunder paths were varied so that the controllers would have to respond to each blunder independently and provide the appropriate instructions to the pilot.

Communication between the blundering aircraft and the monitor controller was also controlled during the simulation. Approximately 70 percent of the blundering aircraft experienced a loss of communication (NORDO) to simulate problems with the radio communication frequency (i.e., stepped on transmission, radio volume turned down). This was accomplished by directing the NSSF aircraft operator to disregard the controller's instructions.

4.3.3 "BREAK" Instruction.

This simulation also tested the effectiveness of the word "BREAK" as a replacement for the word "IMMEDIATELY," when urgent instructions are issued during a blunder situation. Controllers were required to use the word "BREAK," followed by a change in heading. For example, "TWA 492, BREAK right heading 270, climb and maintain 4000."

The suggestion for the term "BREAK" originated from a request by the Air Line Pilots Association (ALPA). They believe the term "IMMEDIATELY" has become overused as a normal instruction and has lost its impact.

4.4 DATA COLLECTION.

Data collection and reduction was accomplished using the Gould SEL computer. The data reduction provided summary files which included a list of all conflicts between aircraft, position, and motion characteristics of each aircraft during a conflict, closest point of approach (CPA) between aircraft, controller messages, response times, and numerous other parameters.

Data were also collected through audio and video recordings, and questionnaires. A 20-channel audio recorder collected the communication between the controllers and the pilots as well as the interaction between the controllers. The video recording was accomplished using 9-track digital computer tapes. The digital tapes made it possible to play the simulation back through the monitors at a later time. Microphones were also used to record the controllers' conversations during each run to permit analysis of controller interaction.

The controllers and the pilots were given questionnaires throughout the simulation and at the conclusion of their participation. The questionnaires addressed the operations of the simulation and the viability of using the 4300 ft runway separation as simulated in the operational environment.

4.5 ASSESSMENT METHODOLOGY.

The ability of controllers to resolve blunders was assessed by statistically analyzing the controlled factors that were predicted to affect controller performance. Descriptive statistics such as frequencies, means, standard deviations, and inferential statistics (Analysis of Variance (ANOVA)) are reported. Analyses were conducted to determine the influence of blunder degree, blunder path, loss of communication, and the number of runways threatened by a blunder on conflict severity. The effectiveness of using the word "BREAK" in place of the word "IMMEDIATELY" in the resolution of a blunder was also evaluated.

Blunders that resulted in a CPA of less than 500 ft were examined individually to determine the factors that contributed to the conflict severity. A comprehensive review of the factors, which included plots of aircraft position, controller-pilot communications, and computer data, was then conducted to determine their operational impact.

The TWG evaluated the results from the simulation to make recommendations concerning approval of the proposed operation. To make their recommendations, the TWG drew upon their understanding of the nature of daily operations, and the knowledge and skills of the controllers.

5. SIMULATION RESULTS.

This section will assess the viability of the triple runway configuration used in this simulation. First, an overview of the air traffic will be presented followed by the analyses. Analyses will include descriptive and inferential statistics on CPA, controller response times, pilot response times, flight simulator performance data, and NSSF aircraft operator performance.

The air traffic generated during this simulation consisted of 2860 aircraft. The air traffic averaged 34 aircraft an hour per runway. An average of 11 blunders were executed per hour. Flight simulators were involved in 69 percent of all blunders. Of the 330 blunders created, the total number of conflicts was 290. A conflict occurred when an aircraft was within 3 nmi longitudinally and 1000 ft vertically of another aircraft.

5.1 PHASE V.a.1 TRIPLE APPROACH ANALYSES.

This section describes the results from the simulation of the triple approach configuration spaced 4300 ft apart using the FMA and a simulated radar with a 4.8 s update rate.

5.1.1 CPA Analyses.

Analyses were conducted on the CPA data. The average CPA was 3657 ft (s.d. = 2268 ft) with the smallest CPA reaching 174 ft.

5.1.1.1 Independent Variables.

An ANOVA was performed on the entire distribution of conflicts to assess the effects of blunder degree (20 or 30 degrees), blunder path (continued descent or maintained altitude), radio communication (COM or NORDO), simulator type (flight simulator or computer-generated aircraft) and wind condition (crosswind or no crosswind) on controller performance. A summary of the blunder executions is shown in table 2.

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The ANOVA indicated that blunder degree and simulator type significantly affected the controllers' ability to resolve conflicts. Twenty-degree blunders resulted in higher CPA's (mean = 4568 ft, s.d. = 2803 ft) than 30-degree blunders (mean = 3271 ft, s.d. = 1894 ft). Additionally, computer-generated aircraft involved in blunders resulted in higher CPA's (mean = 3896 ft, s.d. = 3173 ft) than flight simulators (mean = 3549 ft, s.d. = 1701 ft). Blunder path, communication, and wind condition did not significantly affect CPA's.

TABLE 2.   BLUNDER EXECUTION SUMMARY

	20 Degree		30 Degree	
	NORDO	COM	NORDO	COM
Descend	24	15	97	28
Maintain	12	36	45	33

5.1.1.2   Lower Distribution Analyses.

Conflicts varied in the degree of seriousness as seen by the distribution of CPA values in figure 4. Analyses were conducted on the lower distribution of the CPA's (CPA of less than 1000 ft) where the conflicts were the most serious. A summary of the lower distribution of CPA's is shown in table 3.

Blunder degree, blunder path, and communication influenced controller performance when the separation between aircraft was less than 1000 ft. A total of four conflicts occurred in which the CPA was within 1000 ft. All four conflicts were due to 30 degree blunders in which the blundering aircraft continued its descent. Fifty percent (2) of the blundering aircraft had a loss of communication with controllers, and 75 percent (3) of the conflicts involved flight simulators.

5.1.1.3   Review of the Test Criterion Violation.

A comprehensive review of the conflict that resulted in a test criterion violation (miss distance of less than 500 ft) was performed. The review was conducted to determine whether the TCV was due to extraneous factors in the simulation that would not be present in the operational environment. Video tapes, controller message times, pilot response times, technical observer logs,

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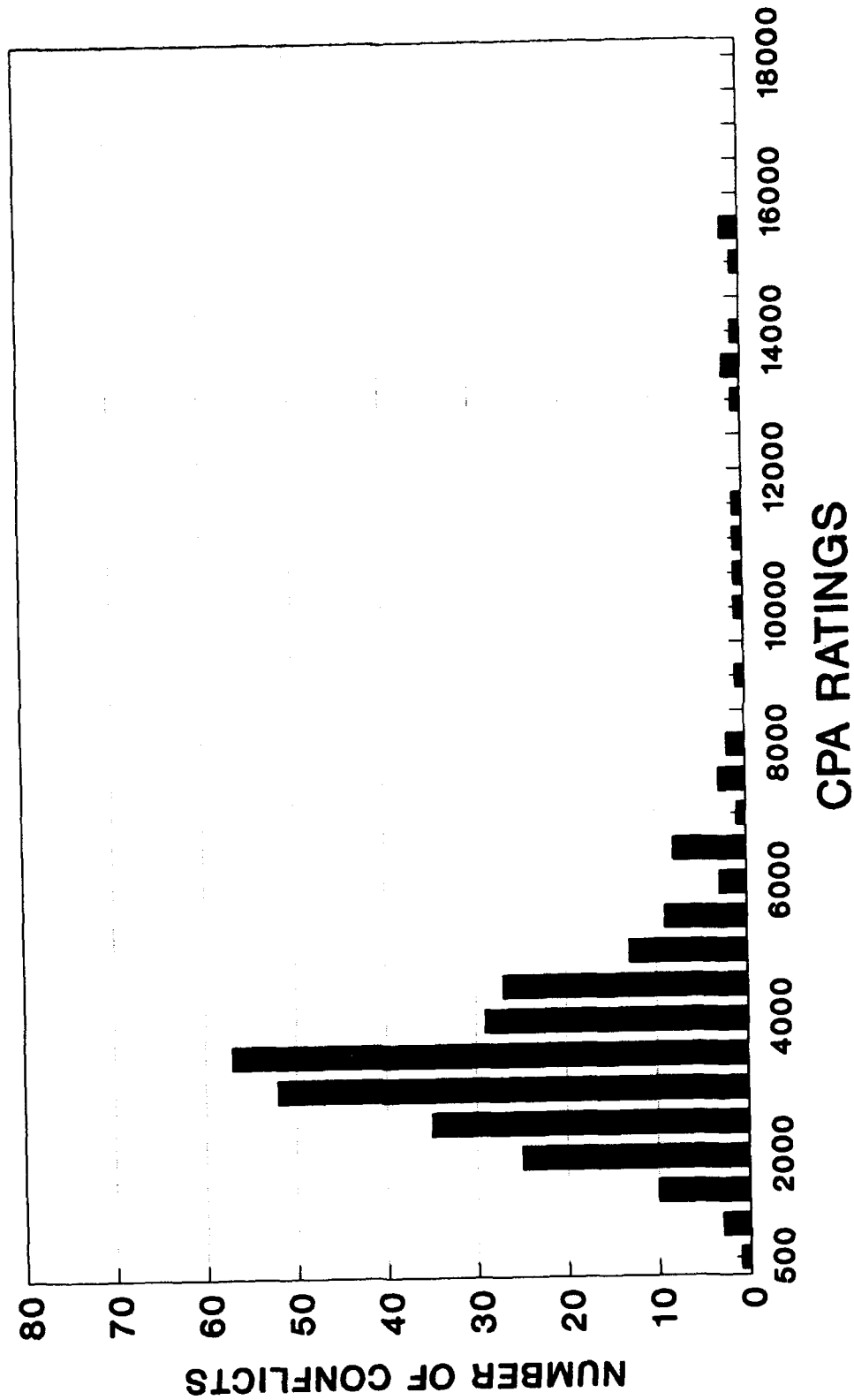
FIGURE 4. DISTRIBUTION OF CPA VALUES

controller incident reports, and aircraft position plots were reviewed.

TABLE 3.   SUMMARY OF THE LOWER DISTRIBUTION OF CPA's

Simulator Type	CPA (ft)	Com	Deg	Path
FLTSIM	846	No	30	Descend
FLTSIM	718	Yes	30	Descend
FLTSIM	598	No	30	Descend
NSSF	174	No	30	Descend

The review indicated that the blunder was a valid TCV. Analysis of the blunder indicated that the pilot of the blundering aircraft did not respond to controller instructions, and the pilot of the evading aircraft was slow to respond to controller instructions. Both aircraft were computer-generated aircraft. The closest point of approach was 174 ft. A description and a plot of the TCV is included in appendix I.

5.1.2 Controller Response Analysis.

Controller response times were calculated from the time the blunder was initiated to the time the controller keyed the microphone to communicate with the pilot of the blundering aircraft. Controller response times averaged 7.70 s, with a standard deviation of 3.40 s. Response times were analyzed with the independent variables specified above. The results indicated that none of the independent variables significantly affected controller response time.

5.1.3 Flight Simulator Pilot Response Analysis.

The amount of time it takes an aircraft to respond to an ATC command has a direct effect on system capacity and safety. Pilot response time is especially critical during the final approach phase of flights made to closely spaced parallel approaches. Pilot response is a difficult variable to measure because it is not easy to determine exactly when a response begins in the continuous process of flight. To resolve this issue, pilot response for the evading aircraft was evaluated by measuring the time it took for the aircraft to achieve a change in heading of 2 degrees, 5 degrees, and 10 degrees after a blunder occurred.

It took an average of 16.17 s from the time a blunder was initiated for the blundering aircraft to reach the NTZ. The data

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indicated that the controller's message to the evading aircraft averaged 3.84 s in length. Evading flight simulators achieved a 2-degree change in heading in an average of 2.46 s prior to the blundering aircraft entering the NTZ. The amount of time needed to complete a 2-degree change in heading was quite variable as a result of total system error (TSE) and pilot technique, and may not be a stable and valid measure of pilot response time.

From the time the blundering aircraft entered the NTZ, it took flight simulators an average of 4.06 s to achieve a change in heading of 5 degrees and 7.86 s for a change in heading of 10 degrees. An ANOVA indicated that the length of time to execute 2, 5, and 10 degree changes of heading were not affected by the blunder degree, blunder path, or communication.

5.2 TOTAL SYSTEM ERROR.

TSE is the difference between the path the aircraft flies and the intended path. This may be expressed as a statistical combination of all sources of navigation error including navigation signal source, propagation, airborne system, and flight technical error (FTE).

In order to discuss the issue of TSE, the layout of the airspace needs to be defined. The airspace is divided into two areas between the runways, the NTZ and the Normal Operating Zone (NOZ). The NTZ is a 2000-ft wide zone equidistant between final approach courses where aircraft are not permitted to enter. If an aircraft enters the NTZ, regulations require the controller to break the adjacent aircraft off of the approach. The NOZ is the area between the NTZ and the extended runway centerline.

TSE becomes an issue as runway spacing decreases. Because the NTZ is fixed at 2000 ft, the NOZ varies with runway separation. As separation between runways decreases, the NOZ decreases, providing less air space for an aircraft to fly along the ILS and a greater opportunity for an aircraft to enter the NTZ. Furthermore, multiple parallel approaches require the localizer intercept to be conducted farther from the runway threshold to provide adequate vertical separation. By moving the intercepts farther from the runway, the glide slope intercepts become varied, increasing the effect of TSE due to the radial dispersion of the localizer signal.

For this simulation, TSE was evaluated with two measures: frequency of NTZ entries and percentage of false breakouts.

5.2.1 NTZ Entry Analyses.

Analyses were conducted on NTZ entries that were not the result of a blunder or a breakout. Both flight simulator and computer-

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generated aircraft data were analyzed to provide a more accurate representation of FTE.

5.2.1.1 Flight Simulator NTZ Entry Analyses.

Analyses were conducted for flight simulator NTZ entries that were not the result of a blunder or breakout (table 4). Of the 486 approaches flown by flight simulators, there were 18 (3.7 percent) NTZ entries. These 18 NTZ entries were the result of 16 flight simulators that entered the NTZ once, and 1 flight simulator that entered the NTZ twice.

TABLE 4.   FLIGHT SIMULATOR NTZ ENTRY DATA

	N13.8	N10	N5	Total NTZ Entries	Percent of Entries
18L	0	0	0	0	0.0
18C	8	9	0	17	94.0
18R	1	0	0	1	6.0
Total NTZ Entries	9	9	0	18	n/a
Percent of NTZ Entries	50.0	50.0	0.0	n/a	100.0

N13.8 =   The aircraft entered the NTZ between $13.8 \leq 10$ nmi of the threshold.
N10   =   The aircraft entered the NTZ between $10 \leq 5$ nmi of the threshold.
N5   =   The aircraft entered the NTZ within 5 nmi of the threshold.

Of the 18 flight simulator NTZ entries, 9 (50.0 percent) occurred between 13.8 and 10 nmi from the threshold and 9 (50.0 percent) occurred between 10 and 5 nmi from the threshold. There were no NTZ entries less than 5 nmi from the threshold. There was a higher frequency of NTZ entries for flight simulators on the center approach (18 NTZ entries or 94.0 percent), than the left approach (0 NTZ entries), or the right approach (1 NTZ entry or 6.0 percent). This was caused by aircraft on the center approach

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having a greater opportunity of entering the NTZ since there was an NTZ on both sides of the approach.

5.2.1.2 Computer-generated Aircraft NTZ Entry Analyses.

Analyses were also conducted for computer-generated aircraft NTZ entries that were not the result of a blunder or a breakout. These data are presented in table 5. Of the 2374 triple approaches flown by computer-generated aircraft, there were 30 (1.0 percent) NTZ entries. These 30 NTZ entries were the result of 28 computer-generated aircraft that entered the NTZ once, and 1 computer-generated aircraft that entered the NTZ twice.

TABLE 5.   COMPUTER-GENERATED AIRCRAFT NTZ ENTRY DATA

	N13.8	N10	N5	Total NTZ Entries	Percent of Entries
18L	0	0	0	0	0.0
18C	3	15	12	30	100.0
18R	0	0	0	0	0.0
Total NTZ Entries	3	15	12	30	n/a
Percent of NTZ Entries	10.0	50.0	40.0	n/a	100.0

N13.8 = The aircraft entered the NTZ between 13.8 $\leq$ 10 nmi of the threshold.
N10   = The aircraft entered the NTZ between 10 $\leq$ 5 nmi of the threshold.
N5   = The aircraft entered the NTZ within 5 nmi of the threshold.

Of the 30 NTZ entries made by computer-generated aircraft, 3 (10.0 percent) occurred between 13.8 and 10 nmi from the threshold, 15 (50.0 percent) occurred between 10 and 5 nmi from the threshold, and 12 (40.0 percent) occurred less than 5 nmi from the threshold. All NTZ entries for computer-generated

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aircraft were made from the center approach (30 NTZ entries or 100.0 percent).

5.2.2 False Breakout Analysis.

False breakouts were typically the result of TSE. They occurred when an aircraft was vectored off an approach for reasons other than a conflict. False breakouts occurred with 127 (4.4 percent) of all aircraft that were not involved in a blunder. As indicated by the chi square, Goodness-of-Fit Test, the number of false breakouts was fairly level across all runs of the simulation (χ^2 = 14.75, p > .05), as shown in figure 5.

The data also indicated that the controllers developed a strategy for handling conflicts for the triple approach configuration. As shown in table 6, aircraft that flew the center approach were not broken out as frequently (32 or 25.2 percent) as aircraft on the left (50 or 39.4 percent) or right (45 or 35.4 percent) approaches. It appeared that it was safer for controllers to use an altitude correction to resolve a conflict on the center approach because heading correction would have directed the aircraft across another approach course.

5.3 QUESTIONNAIRE ANALYSES.

This section details the findings of the controller and pilot questionnaire analyses.

5.3.1 Post-Run Controller Questionnaire Analysis.

The Post-Run Controller Questionnaire asked the controllers to rate their activity level, ability to control traffic using the FMA, stress level, time to break-out endangered aircraft, and mental workload throughout the simulation. This questionnaire is included as appendix E.

5.3.1.1 Activity Level.

The first question asked controllers to rate the level of activity required for the run. The rating scale ranged from 1 (minimal) to 7 (intense). Controllers rated their activity level as moderate (3.1). A chi square was performed to investigate whether runway position (18R, 18C, 18L) affected activity level. No significant differences existed in the ratings as a result of runway assignment.

5.3.1.2 Traffic Control.

The controllers' ability to control traffic using the FMA was rated from 1 (poor) to 7 (excellent). The average rating was 5.9

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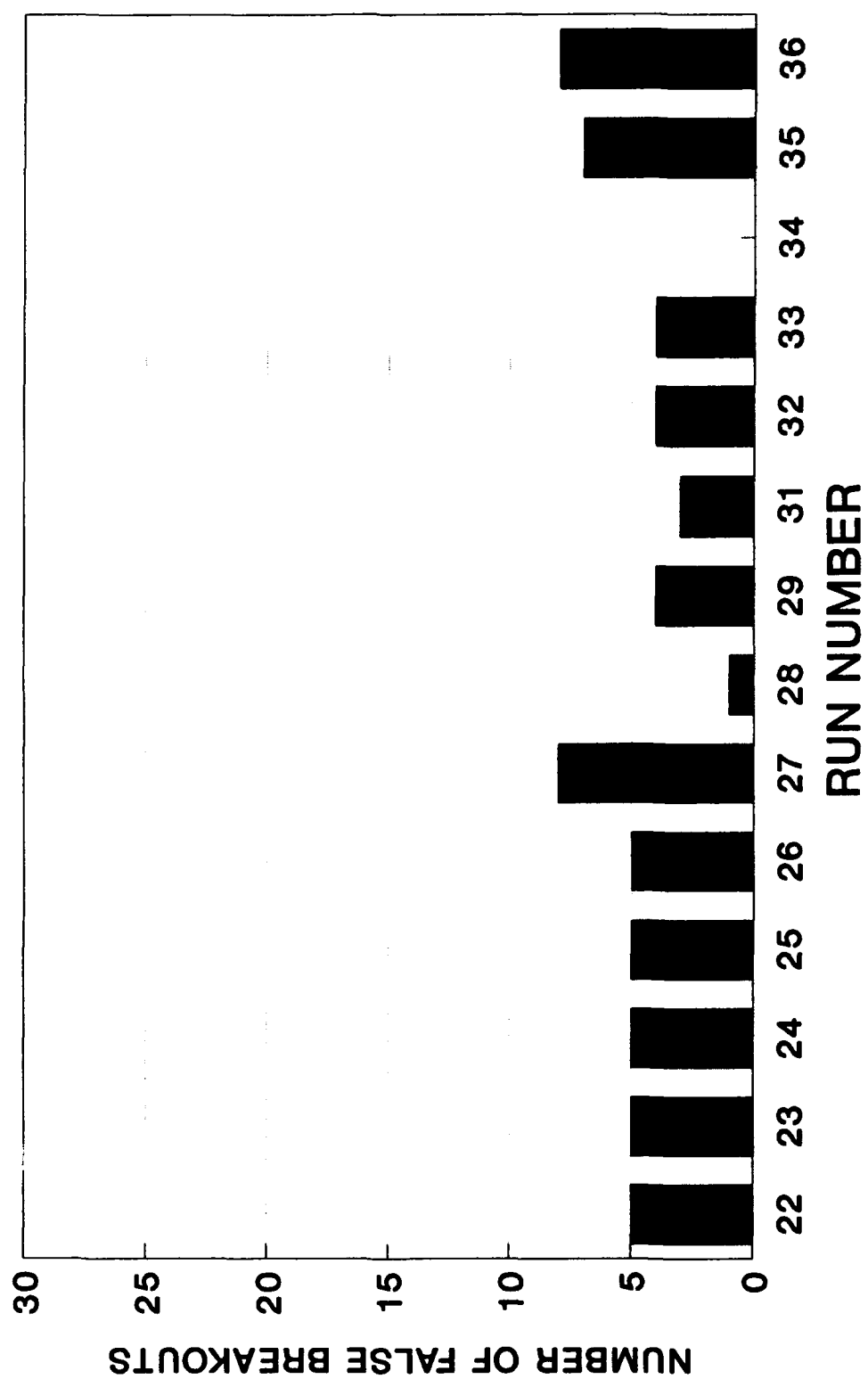
FIGURE 5. NUMBER OF FALSE BREAKOUTS

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(good). As in the previous question, no significant differences were found in controller ratings that were attributable to runway assignment.

TABLE 6.   FREQUENCY OF FALSE BREAKOUTS PER RUNWAY

Runway	Number of False Breakouts	Percent of False Breakouts
18L	50	39.4
18C	32	25.2
18R	45	35.4
Totals	127	100.0

5.3.1.3   Stress Level.

Perceived level of stress was rated in the third question on a scale ranging from 1 (slight) to 7 (extreme). The average rating was 3.0. This rating indicated that controllers experienced a moderate amount of stress throughout the study. A chi square indicated that no significant differences in ratings were attributable to runway assignment.

5.3.1.4   Break-Out Time.

The fourth question asked controllers if they had adequate time to break-out endangered aircraft. The frequency of yes responses was 100 percent.

5.3.1.5   Mental Workload.

The last question asked controllers to provide an overall rating of the workload they experienced during the run. The basis for rating workload was mental effort and ease of traffic handling. Controllers reported that an acceptable to moderately high level of mental effort (3.2) was required to maintain "satisfactory traffic handling." A chi square performed on the data indicated that no significant differences in ratings were attributable to runway assignment.

5.3.2   Post-Simulation Controller Questionnaire.

Controllers were also given a questionnaire at the end of the simulation. The questionnaire addressed the simulation operation, the equipment, the plausibility of using the 4300 ft runway separation as simulated in the operational environment,

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and comments on specific terminology that was used for the evasive maneuver.

All controllers agreed that they had adequate training and information to perform the monitor controller task. The controllers all responded that the air traffic was realistically represented in the simulation. Controllers also agreed that the portrayal of a blunder was realistic both audibly and visually.

Two questions specifically addressed information on the displays. All controllers thought that adequate information was provided in the aircraft data block to control the air traffic effectively. One of the six controllers preferred the victim aircraft to turn red in lieu of yellow.

Five of the six controllers (83 percent) strongly agreed that the conditions in the simulation (i.e., volume of traffic, procedures, runway separation) would be workable at their facility. One controller was uncertain. However, all six controllers agreed that independent instrument flight rules (IFR) approaches to runways separated by 4300 ft could be safely conducted as simulated.

5.3.2.1 "BREAK" Instruction.

In response to ALPA's request to use the term "BREAK" in the evasive maneuver instead of the term "IMMEDIATELY," the controllers responded that the term "BREAK" is defined as a phase of flight in the recovery of military aircraft to the Visual Flight Rules (VFR) pattern. One controller commented, "Break is that point where the first 180 degree turn is made from initial in the overhead pattern." Therefore, the use of the term "BREAK" in simultaneous approaches would be uncharacteristic for its normal definition in controller phraseology.

Blunders are a rare event and, in all likelihood, one which most controllers will never witness. In this respect, it is unrealistic to make both pilots and controllers responsible to apply the word "BREAK" in an actual blunder. The controller will likely use the word "IMMEDIATELY" to request immediate pilot compliance with a control request.

5.3.3 Pilot Questionnaire Data.

The Pilot Questionnaire was administered to the pilots by the site coordinator at the end of each approach. It requested the pilots to rate their workload level, ability to respond to a breakout command, type of approach, and level of stress. The Pilot Questionnaire also collected pilot comments on the specific terminology that was used for evasive maneuvers.

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5.3.3.1 Workload Level.

The first question asked pilots to rate the workload level required during each approach. The rating scale ranged from 1 (minimal) to 10 (intense). The average rating was 2.8, indicating a minimal level of workload was required throughout the simulation.

5.3.3.2 Break-out.

Pilots were asked if they were able to follow the controllers' instructions for an immediate break-out. The frequency of yes responses was 93.2 percent. Controller error (poor annunciation, incorrect call sign), pilot error (not familiar with call sign), and stepped on transmissions contributed to the frequency of no responses.

5.3.3.3 Type of Approach.

During this simulation pilots had the option of choosing the type of approach they wanted to make. Pilots chose to use raw data in 51.8 percent of the approaches, the flight director in 33 percent of the approaches, and the autopilot in 15.2 percent of the approaches.

5.3.3.4 Stress Level.

After every approach pilots rated their level of stress. The scale ranged from 1 (minimal) to 10 (intense). Pilots rated their average level of stress to be minimal, 2.1.

5.3.3.5 "BREAK" Instruction.

Flight simulator pilots also commented on "BREAK," the evasive maneuver terminology, used by the controllers. The majority of the pilots agreed the term "BREAK" would not be a practical replacement for the term "IMMEDIATELY." Their reasoning was that the term "BREAK" is already used by controllers to indicate a break in communications. Therefore, the pilots thought that the additional meaning of the term "BREAK" would result in confusion.

6. DISCUSSION.

This discussion is divided into two sections. The first section will discuss the simulation results; the second section will discuss some of the human factors issues associated with the FMA.

6.1 SIMULATION RESULTS.

The simulation was designed to test the procedures for triple simultaneous parallel ILS approaches spaced 4300 ft apart using the FMA and a simulated radar with a 4.8 s update rate.

Controllers were asked to resolve conflicts that rarely occur in the operational environment. The conflicts were the result of aircraft blundering (20 or 30 degrees) toward an adjacent approach. Often the blundering aircraft simulated a loss of communication.

Analyses of the data indicated that controllers were able to maintain the test criterion aircraft miss distance of 500 ft or greater in 99.7 percent of the blunders. Only one blunder during the simulation resulted in a TCV. The review of the TCV revealed that the lack of response from the pilot of the blundering aircraft and the slow pilot response time of the evading aircraft caused the two aircraft to come within 500 ft of each other.

A risk assessment is being conducted on the data from this simulation. The findings of the risk assessment will determine the impact of the proposed operations on the current level of safety. The risk assessment will be published at a later date in a separate document. This document will be included as Volume II of this report.

The controller questionnaire asked the controllers to rate their activity level (moderate), ability to control traffic using the FMA (good), stress level (moderate), time to break-out endangered aircraft (adequate), and mental workload (acceptable to moderate) throughout the simulation. The majority of controllers (83 percent) strongly agreed that the conditions in the simulation (i.e., volume of traffic, procedures, runway separation) would be workable at their facility. One controller was uncertain. However, when controllers were asked if independent IFR approaches to runways separated by 4300 ft could be safely conducted as simulated, all six agreed.

The pilot questionnaire included workload level, the pilots ability to respond to a break-out command, the type of approach used on the ILS, and the level of stress. The pilots indicated that a minimal level of workload and stress was experienced while conducting approaches during the simulation. Ninety-three percent of the pilots were able to respond immediately to controller instructions. The pilots preferred to fly the approach using raw data (52 percent) over using the flight director (33 percent) or the auto-pilot (15 percent).

Phase IV.a, conducted in the spring 1990, examined 4300 ft runway separation using the ARTS IIIA display system. A direct comparison cannot be made between Phase IV.a and Phase V.a.1 due to differences in the traffic samples, the addition of more flight simulators, the FTE model, and the controller questionnaires requested slightly different information. However, the results can be directly compared with respect to the number of TCV's and general controller feedback.

The ARTS IIIA is the display type currently used in most high traffic TRACON's. The ARTS IIIA displays both primary and secondary surveillance echoes. The display monitor is a 36-inch diameter circular tube that displays targets and information in green. The ARTS system overlays alphanumeric information provided by the data processing system on the primary and secondary radar information.

In contrast, the FMA has several unique features that may have enhanced the controllers' performance during the Phase V.a.1 simulation. These display features are high resolution, color, range magnification capabilities, and visual and audio alerts. The color enables areas of the screen to be highlighted; for example, the runway and the extended runway centerline were displayed in white on a black background. The NTZ was outlined in red. Additionally, light blue lines were displayed parallel to the extended runway centerline to mark 200-ft intervals between the NTZ and the ILS course. The color also provides the controller with a visual alert for impending NTZ entries.

The FMA has independent x-y (lat-long) range magnification. This allows the controller to magnify lateral runway spacings independent of the longitudinal distances. During Phase V.a.1, the magnification was set at 8 to 1.8. This display scale may have provided the controllers with an improved capability to detect aircraft movement away from the extended runway centerline.

In this study, controllers had a 99.7 percent success rate. In comparison, controllers only generated a 90 percent success rate in the Phase IV.a simulation. This indicates that Phase IV.a had a greater TCV potential as indicated by the differences in the number of TCV's, 1 in Phase V.a.1, and 23 in Phase IV.a.

Controllers generally reported that their activity levels, stress levels, and mental workload levels were below moderate for the Phase V.a.1 simulation as opposed to the overall moderate rating that they reported in Phase IV.a. It appeared that less mental workload was experienced when the controllers used the new display system.

Additional comments made by the controllers specifically addressed the "BREAK" command used for evasive maneuvers. Six of eight controllers did not like the use of the term "BREAK." One controller thought the term was unnecessary. Pilots commented that the term "BREAK" is already used during normal operations to indicate a break in communications.

6.2 HUMAN FACTORS ISSUES.

This simulation provided an initial look at some of the improvements in controller performance through enhanced display

system designs. Although the simulation was not designed specifically to examine human factors issues in the ATC environment, many human factors issues can be addressed. Four issues which the simulation addressed were the advantage of high resolution color displays, the differential lat-long magnification, aircraft predictor lines, and the controller alerts.

6.2.1 Display Resolution.

The controllers' ability to differentiate aircraft targets on the ARTS display was one of the issues discussed in the controller report for Phase IV.a. (CTA, 1991) The controllers were unable to detect relatively small aircraft movements and were not able to determine distances between targets. This could have been due to the similar color and the lack of distinction between the images of the airspace and the lines inherent in the ARTS IIIA displays. The high resolution of the FMA display provided well-defined targets which seemed to be easily differentiated because of the color capability of the FMA.

6.2.2 Independent Display Magnification.

The independent lat-long magnification capability of the FMA may have enabled the controllers to detect ILS deviations more readily. This capability signifies an improvement over the ARTS display system's inflexible magnification capabilities. Figure 6 illustrates the 1:1 X-Y magnification ratio of the ARTS display and the 8:1.8 X-Y magnification ratio of the FMA. The 8:1.8 ratio used in this simulation appeared to work well, but should be investigated further to determine optimal ratios.

While the independent lat-long magnification may enable controllers to detect ILS deviations more readily, it does have a drawback. When the X and Y axes are magnified independently of one another, it causes the relationship between the two axes to no longer be balanced at a one-to-one ratio. This could complicate the controller's ability to determine an aircraft's heading when the aircraft is not going totally lateral or totally vertical.

6.2.3 Aircraft Position Predictors.

Both the FMA and the ARTS IIIA displays provide information to the controller about the aircraft's previous positions. The ARTS IIIA relies on Phosphor Persistence and the FMA has a controller adjustable target trail. The FMA has an added benefit of presenting future aircraft position through aircraft predictor lines. The predictor lines can be adjusted for length (duration) by the controllers. Generally, they were set to 10 seconds during this study.

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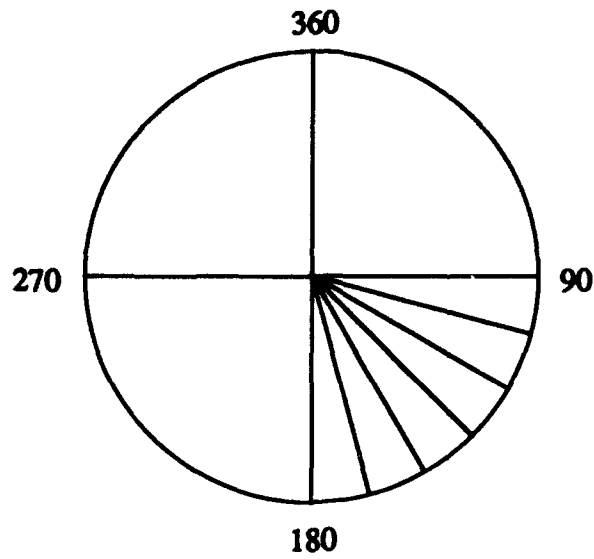
1:1 Ratio of the ARTS Display
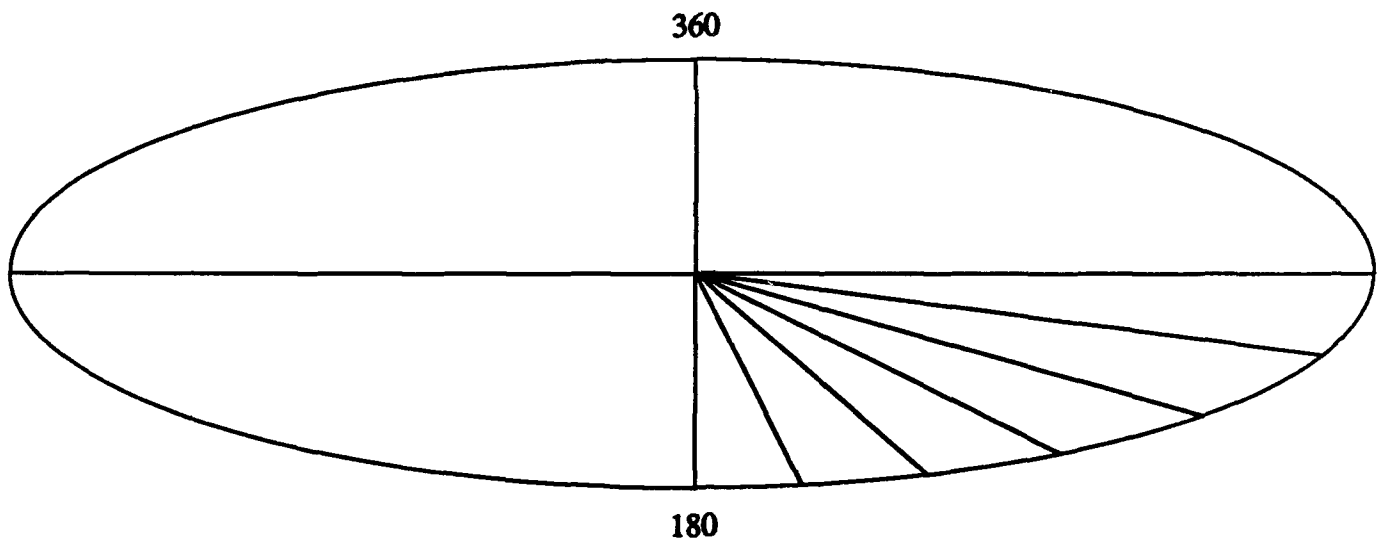
8:1.8 Ratio of the FMA Display

FIGURE 6.   INDEPENDENT MAGNIFICATION AND PRESENTATION OF DISPLAY AXES

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The algorithm for the predictor lines used the aircraft's current position, heading, and speed to determine its future position. This enabled controllers to detect rapid changes in direction, such as a blunder, more readily. This algorithm also makes the predictor susceptible to radar error, thus, resulting in a "twitching" motion. Although false breakouts were not prevalent in this simulation, the current implementation of the predictor algorithm may produce unacceptably large numbers of false breakouts in operations with close runway spacings. An algorithm which uses a weighted average of several previous positions would provide a more reliable prediction with a small delay. This would effectively reduce the predictor "twitching" produced by radar error yet provide a more conservative estimate of future aircraft position.

6.2.4 Controller Alerts.

The feature which probably contributed the most to the improved controller performance and reduced controller workload was the controller alerts. The FMA display system provides controllers with both visual and audio alerts of impending and actual NTZ entries. The aircraft target and data block change from green to yellow and an auditory warning which identifies the aircraft call sign is given when an NTZ entry is predicted to occur within 10 s. Using the prediction algorithm described above, the prediction is based upon current aircraft position, speed, and heading. If an aircraft proceeds and enters the NTZ, the aircraft target and data block change color from yellow to red.

This feature seemed to effectively alert the controllers and assist them in early detection of blunders. The earlier detection appeared to have provided controllers with increased time to either correct the course of the blundering aircraft or to issue missed approach instructions to pilots of aircraft on adjacent parallel approaches.

7. CONCLUSIONS.

This study was part of an on-going effort to evaluate plans for increasing air traffic capacity and to evaluate the feasibility of using multiple simultaneous parallel Instrument Landing System (ILS) approaches. The objective of this study was to evaluate the ability of controllers who were experienced with multiple parallel approach operations to handle approach traffic during Instrument Meteorological Conditions (IMC) to a proposed parallel runway airport configuration, using a real-time, interactive, air traffic control (ATC) simulation. It should be kept in mind that, like the output of all experimental evaluations, the results of this study should not be extrapolated to situations which contain variables other than those tested in this study.

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The proposed configuration consisted of three parallel runways spaced 4300 feet (ft) apart. The generic airport had a field elevation of 600 ft. A radar system with a 4.8 second (s) update rate and 2 milliradian accuracy was simulated and implemented into the ATC operations. The Final Monitor Aid (FMA) (high resolution color display equipped with the controller alert system hardware/software used in the Precision Runway Monitor (PRM) system) was used for the final approach monitor positions. The air traffic consisted of both flight simulators and computer-generated aircraft which emulated turbojets, turboprops, and propeller driven aircraft.

Triple simultaneous parallel ILS approaches were simulated with controllers monitoring traffic on the approach localizers. To challenge the system, scenarios were developed to create conflicts between aircraft. Blunders were generated by having some of the simulated aircraft deviate from the localizer by either 20 or 30 degrees. Furthermore, 70 percent of the blundering aircraft simulated a total loss of radio communication (NORDO) with the controllers. The simulation also tested the effectiveness of the word "BREAK" as a replacement for the word "IMMEDIATELY" when urgent instructions were issued during a blunder situation.

The central issue in the study was the ability of the controllers to maintain distance between a blundering aircraft and aircraft on adjacent parallel approaches. Two questions were to be answered:

a. Would the controllers be able to maintain the test criterion miss distance, of at least 500 ft between aircraft, in response to blunders occurring in the proposed triple approach configuration?

b. Do the controllers, technical observers, the Multiple Parallel Technical Work Group (TWG), and other Federal Aviation Administration management observers agree that the operation of the proposed triple simultaneous parallel ILS approaches is acceptable, achievable, and safe as simulated?

The results indicated that controllers were able to resolve 99.7 percent of the conflicts in the simulation. Of the 290 conflicts, only 1 resulted in aircraft violating the criterion miss distance of 500 ft. In addition, the controllers indicated that the displays provided them with adequate time to initiate blunder resolution maneuvers successfully.

Controllers experienced a moderate level of workload while using the FMA. The controllers stated that the FMA enabled them to effectively resolve blunders. As indicated in Appendix D, Controller Report, the controllers concluded that the triple simultaneous parallel ILS approaches with runway centerlines

spaced 4300 ft apart would be a "safe and viable operation" using current technology radar systems and the FMA.

Pilots experienced minimal levels of workload and stress while conducting approaches during the simulation. They also indicated that they were generally able to execute the controller's instructions immediately.

In response to the Airline Pilots Association's (ALPA) request to use the term "BREAK" in the evasive maneuver instead of the term "IMMEDIATELY," six of eight controllers did not like the use of the term "BREAK." One controller thought the term was unnecessary. The controllers believed the use of the term "BREAK" in simultaneous approaches would be uncharacteristic for its normal definition in controller phraseology. The majority of the pilots agreed the term "BREAK" would not be a practical replacement for the term "IMMEDIATELY." Their reasoning was the term "BREAK" is already used by controllers to indicate a break in communications, therefore, the additional meaning of the term "BREAK" may result in confusion.

Total system error (TSE) is the difference between the path the aircraft flies and the intended path. This may be expressed as a statistical combination of all sources of navigation error including navigation signal source, propagation, airborne system, and flight technical error (FTE). For this simulation, TSE was evaluated with two measures: frequency of No Transgression Zone (NTZ) entries that were not the result of a blunder or a breakout, and percentage of false breakouts.

Of the 486 approaches flown by flight simulators, there were 18 (3.7 percent) NTZ entries. Of the 2374 triple approaches flown by computer-generated aircraft, there were 30 (1.0 percent) NTZ entries. False breakouts occurred when an aircraft was vectored off an approach for reasons other than a conflict. False breakouts occurred with 127 (4.4 percent) of all aircraft that were not involved in a blunder.

The TWG, composed of individuals from the Office of System Capacity and Requirements, Air Traffic, Flight Standards, Aviation System Standards, and Operations personnel, participated in the simulation and evaluated the simulation findings. Based upon the TWG's understanding of daily air traffic operations, the knowledge and skills of controllers, and the contingencies which must be accounted for, the TWG determined that the triple simultaneous parallel ILS approach operation spaced at 4300 ft is acceptable using the FMA and the simulated ASR radar with a 4.8 s update rate.

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GLOSSARY

Airport Surveillance Radar (ASR) - Approach control radar used to detect and display an aircraft's position in the terminal area. ASR provides range and azimuth information but does not provide elevation data. Coverage of the ASR can extend up to 60 miles.

Analysis of Variance (ANOVA) - A statistical analysis involving the comparison of deviations between groups and within groups reflecting different sources of variability.

Automated Radar Terminal System (ARTS) IIIA - The Radar Tracking and Beacon Tracking Level (RT&BTL) of the modular, programmable automated radar terminal system. ARTS IIIA detects, tracks, and predicts primary as well as secondary radar-derived aircraft targe' ;. This more sophisticated computer driven system upgrades the e₋isting ARTS III system by providing improved tracking, continuous data recording, and failsoft capabilities.

Blunder - An unexpected turn by an aircraft already established on the localizer toward another aircraft.

Closest Point of Approach (CPA) - The smallest slant range distance between two aircraft in conflict.

Computer-Generated Aircraft - Targets generated by the National Airspace System Simulation Support Facility's (NSSF) Gould SEL Computer. Computer-generated aircraft were used to provide additional traffic and to initiate blunders.

Conflict - When an aircraft is within 3 nmi longitudinally and/or 1000 ft vertically of another aircraft.

Dependently Sequenced Approaches - When used in conjunction with parallel runways, instrument landing system approaches conducted at many facilities in the United States where at least 2 nmi separation must be maintained between aircraft on the parallel approaches in addition to the standard radar separation required between aircraft on the same approach.

Final Monitor Aid (FMA) - A high resolution color display that is equipped with the controller alert system hardware/software which is used in the Precision Runway Monitor (PRM) system. The display includes alert algorithms providing the target predictors, a color change alert when a target penetrates or is predicted to penetrate the No Transgression Zone (NTZ), a color change alert if the aircraft transponder becomes inoperative, synthesized voice alerts, digital mapping, and like features contained in the PRM system.

Flight Technical Error (FTE) - The accuracy with which the pilot controls the aircraft as measured by the indicated aircraft position with respect to the indicated command or desired position. It does not include procedural blunders. USAGE: FTE is the actual error determined by analysis of airborne/simulator flight test data.

Glide Slope Intercept - The minimum altitude to intercept the glide slope during a precision approach. The intersection of the published intercept altitude with the glide slope, designated on Government charts by the lightning bolt symbol, is the precision Final Approach Fix (FAF); however, when ATC directs a lower altitude, the resultant lower intercept position is then the FAF.

Instrument Flight Rules (IFR) - Regulations governing procedures when conducting instrument flight. Also a term used by pilots and controllers to indicate type of flight plan.

Instrument Landing System (ILS) - A precision instrument approach system which normally consists of the following electronic components and visual aids; localizer, glide slope, outer marker, middle marker, and approach lights.

Instrument Meteorological Conditions (IMC) - Any weather condition which causes a pilot to navigate an aircraft solely via cockpit instrumentation. Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling less than minima specified for visual meteorological conditions.

Missed Approach - A maneuver conducted by a pilot when an instrument approach cannot be completed to a landing. The route of flight and altitude are shown on instrument approach procedure charts. A pilot executing a missed approach prior to the Missed Approach Point (MAP) must continue along the final approach to the MAP. The pilot may climb immediately to the altitude specified in the missed approach procedure.

NAS Simulation Support Facility (NSSF) - The facility located at the FAA Technical Center, which houses individuals who "pilot" the simulation aircraft, and the equipment used to accomplish this task.

National Airspace System (NAS) - The common network of U.S. airspace; air navigation facilities, equipment and services, airports or landing areas; aeronautical charts, information and services; rules, regulations and procedures, technical information and manpower and material. Included are system components shared jointly with the military.

Normal Operating Zone (NOZ) - The area between the runway and the No Transgression Zone (NTZ).

No Transgression Zone (NTZ) - An area 2000-ft wide established equidistant between the final approach courses of parallel runways, which aircraft are not permitted to enter. The area begins at the glide slope intercept point for each runway, and extends to a point 1/2 mile beyond the departure end of each runway.

NSSF Aircraft Operators - Personnel, not necessarily pilots, trained to operate the computer-generated aircraft via a specialized keyboard at the FAA Technical Center NSSF complex.

Outer Marker (OM) - A marker beacon at or near the glide slope intercept altitude of an ILS approach. It is keyed to transmit two dashes per second on a 400 Hz tone, which is received aurally and visually by compatible airborne equipment. The OM is normally located 4 to 7 miles from the runway threshold on the extended centerline of the runway.

Parallel ILS Approaches - Approaches to parallel runways by IFR aircraft which, when established inbound toward the airport on the adjacent final approach courses, are radar-separated by at least 2 miles.

Precision Runway Monitor (PRM) System - Provides air traffic controllers with high precision secondary surveillance data for aircraft on final approach to closely spaced parallel runways. High resolution color monitoring displays (FMA's) are required to present surveillance track data to controllers along with detailed maps depicting approaches and No Transgression Zones (NTZ).

Simultaneous ILS Approaches - An approach system permitting simultaneous ILS/MLS approaches to airports having parallel runways separated by at least 4300 feet between centerlines. Integral parts of the total system are ILS/MLS, radar, communications, ATC procedures and appropriate airborne equipment.

Test Criterion Violation (TCV) - A conflict resulting in a slant range miss distance (CPA) of less than 500 ft. The test criterion for simultaneous independent ILS approaches is 500 ft.

Technical Observer - An individual who monitors each control position visually and aurally during each simulation run. Their duties include: documenting discrepancies between issued air traffic control instructions and actual aircraft responses; assist in alerting responsible parties to correct any problems which may occur during the test (e.g., computer failure, stuck microphone); assist controllers in preparation of reports, and assist in final evaluation of data in order to prepare a Technical Observer report at the end of the simulation.

Total System Error (TSE) - The difference between the path the aircraft flies and the intended path. This may be expressed as a statistical combination of all sources of navigation error including navigation signal source, propagation, airborne system, and Flight Technical Error (FTE).

Visual Meteorological Conditions (VMC) - Meteorological conditions expressed in terms of visibility, distance from cloud, and ceiling equal to or better than specified minima.

Wanderer - An aircraft whose navigational performance is so poor that it may deviate into the NTZ unless a controller takes corrective action. If no action is taken, the aircraft will return on its own to the localizer.

APPENDIX A

MULTIPLE PARALLEL APPROACH PROGRAM SUMMARY

MULTIPLE PARALLEL APPROACH PROGRAM

PHASE I.

The Dallas/Ft. Worth (DFW) Phase I Simulation was conducted from May 16 to June 10, 1988. This two-part study was designed to test selected aspects of the quadruple approach operation. The first part of the simulation evaluated concepts for using additional routes, navigational aids, runways, Air Route Traffic Control Center (ARTCC) Complex and Terminal Radar Approach Control (TRACON) facility traffic flows in the implementation of quadruple approaches.

The second part focused on the quadruple Instrument Landing System (ILS) parallel approach operation. The runway configuration consisted of the two existing 11,388-foot (ft) runways (17L and 18R), which have a centerline separation of 8800 ft, and two new 6000-ft runways. The first new runway, 16R, was 5800 ft west of the 18R centerline, and the second, 16L, was 5000 ft east of the 17L centerline. Controllers used Sanders/DEDS displays, and an ASR-9 with a 4.8 second radar update rate was simulated.

The analyses indicated that blunders which threatened more than one approach were no more dangerous than blunders which threatened only one approach. Additionally, the controllers agreed that the new configuration maximized the use of enroute airspace (Paul, L., et al., 1989, Art 2). Based upon this simulation, triple parallel ILS approaches were approved for DFW with the restriction that only turboprop aircraft land on 16L.

PHASE II.

This simulation was conducted from September 25 to October 5, 1989. The simulation assessed the DFW triple simultaneous ILS approaches, departures, and missed approach operations. As with Phase I, controllers used Sanders/DEDS displays and a simulated ASR-9 with a 4.8 second radar update rate. The airport configuration used a new 8500-foot runway, 16L, located 5000 ft east of the runway 17L centerline.

Analyses indicated that, in the triple approach operation, controllers were able to intervene in the event of a blunder and provide distances between conflicting aircraft that were comparable to the distances achieved in the dual approach operation. No blunder in either the dual or the triple approach operation resulted in a slant range miss distance of 1100 ft or less.

Additionally, the controllers, controller observers, and Air Traffic Control (ATC) management observers concluded that the proposed triple approach operation at DFW was acceptable,

achievable, and safe. (CTA, 1990) Results from this simulation supported the approval of turbojets operating on the three proposed parallel approaches. Further, in December 1989 the triple approach operation was approved at DFW as a result of the simulation study.

PHASE III.

The Phase III Simulation reconsidered the DFW quadruple simultaneous ILS approach and departure operation assessed in Phase I, with changes in runway lengths and traffic samples. Runway 16L was 8500 ft long and 16R was 9900 ft long. The traffic samples included propeller driven, turboprop, and turbojet aircraft on the outer runways and turbojet aircraft only on the inside runways. Controllers used Sanders/DEDS displays, and an ASR-9 with a 4.8 second (s) radar update rate was simulated.

Findings of the simulation indicated that air traffic controllers were able to maintain miss distances, between aircraft, in excess of the 500-ft test criterion. There were no operational differences between the dual and quadruple approach conditions. Controllers, controller observers, and ATC management concluded that the quadruple approach operation is a "safe, efficient, and workable procedure." (CTA, 1990, Art 2) As a result of this simulation study, quadruple approach operations were approved at DFW in May 1990.

PHASE IV.

The purpose of the Phase IV Simulation was to develop national standards for triple simultaneous ILS approach operations using a simulated radar system, with a 4.8 s update rate and a current display system, Automated Radar Terminal System (ARTS) IIIA. Phase IV was conducted in two simulations:

1. Phase IV.a assessed triple simultaneous ILS approaches to runways spaced 4300 ft apart with even thresholds. This simulation included the integration of a Phase II B-727 flight simulator and a General Aviation Trainer (GAT) flight simulator. This simulation was conducted from April 24 to May 3, 1990.

The results of this simulation indicated that triple simultaneous parallel ILS approaches, with ARTS IIIA displays and radar with a 4.8 s update rate, was not acceptable. The relatively poor resolution of the displays and the update rate of the radar did not enable controllers to resolve the simulation induced conflicts. Based upon this simulation, the recommendation for incorporating the Final Monitor Aid (FMA) and high update rate radars was made. The follow-on study (Phase V.a.1) using the improved displays and radar system is discussed below.

2.   Phase IV.b assessed triple simultaneous ILS approaches to
runways spaced 5000 ft apart with even thresholds.   This
simulation included the integration of two Phase II B-727 and one
GAT flight simulators.   This simulation was conducted from
September 17 to 28, 1990.   Findings indicated that triple
simultaneous parallel ILS approach operations with runways spaced
5000 ft apart are acceptable using radar with a 4.8 s update rate
and the ARTS IIIA displays.

PHASE V.

Phase V was conducted in eight subphases.   All Phase V subphases
incorporated the FMA.   Five flight simulators as well as
computer-generated aircraft were integrated into each Phase V
simulation.

1.   Subphases V.b.1 and V.b.2 assessed dual and triple
simultaneous parallel ILS approach operations to runways spaced
3000 ft apart using a simulated radar with an update rate of 1.0
s. The dual approach simulation was conducted March 18 to 27,
1991, and the triple approach simulation was conducted March 28
to April 5, 1991.   It was determined that due to the high
frequency of false breakouts due to Total System Error (TSE) and
the congestion on the communication frequencies, dual and triple
simultaneous parallel approach operations with 3000 ft runway
separation would not be acceptable.

2.   Subphase V.c assessed triple simultaneous parallel ILS
approach operations to runways spaced 3400 ft apart using a
simulated "back- to-back" radar with a 2.4 s update rate.   This
subphase was conducted May 6 to 14, 1991.   The test report for
this simulation is currently being finalized.

3.   Subphase V.a.1 assessed triple simultaneous parallel ILS
approach operations to runways spaced 4300 ft apart, using a
simulated radar with a 4.8 s update rate.   This subphase was
conducted May 15 to 24, 1991. The results of this simulation are
presented in this document.

4.   Subphase V.b.3 assessed dual simultaneous parallel ILS
approach operations to runways spaced 3000 ft apart with a 1-
degree localizer offset to determine the effect of TSE.   The
simulation used the FMA and a simulated radar with a 1.0 s update
rate.   This subphase was conducted September 26 to October 4,
1991.   Based on preliminary results, it was determined that an
additional amount of data will need to be collected in order to
make a conclusive statement on the outcome of this simulation.

5.   Subphase V.a.2 assessed triple simultaneous parallel ILS
approach operations to runways spaced 4000 ft apart using a
simulated radar with an update rate of 4.8 s.   This subphase was
conducted September 24 to October 4, 1991.   Based on preliminary

results, it was determined that an additional amount of data will need to be collected in order to make a conclusive statement on the outcome of this simulation.

6.   Subphase V.d.1 evaluated a tool designed to assist test directors in determining the best time to create a blunder situation.   This subphase was conducted February 3 to 7 and February 24 to 28, 1991.

7.   Subphase V.d.2 assessed triple simultaneous parallel ILS approach operations to runways spaced 3400 ft apart using simulated radar sensors with an update rate of 1.0 s.   This subphase was conducted March 2 to 13, 1992.   The data from this simulation are currently being analyzed.

8.   Subphase V.a.2.2 re-examined triple simultaneous parallel ILS approach operations to runways spaced 4000 ft apart. Controllers used FMA displays and a simulated radar with a 4.8 s update rate.   This subphase was conducted July 27 to August 14, 1992, and the results are currently being analyzed.

DENSITY ALTITUDE STUDY.

The Density Altitude Study, conducted September 8 to 25, 1992, examined the effects of high density altitude on triple and quadruple parallel approach operations.   Components of the generic airport configuration included a field elevation of 5431 ft, and runways spaced 7600, 5280, and 5348 ft apart. Controllers used ARTS/DEDS displays, and a radar with a 4.8 s update rate was simulated.

DENVER INTERNATIONAL AIRPORT (DIA).

The DIA simulation examined proposed triple parallel approach operations at the new Denver International Airport.   The simulation was conducted from November 16 to December 17, 1992. Components of the generic airport configuration included a field elevation of 5431 ft, and runways spaced 7600 and 5280 ft apart. From November 16 to 18, 1992, controllers used FDADs, and a radar with a 4.8 s update rate was simulated.   Beginning November 18, 1992, the remainder of the simulation was conducted with controllers using the FMA displays.

APPENDIX B

CONTROLLER RUN ASSIGNMENTS

PHASE V.a.1 CONTROLLER RUN ASSIGNMENTS

Date	Run	18R	18C	18L	Traffic Samples
5/15	22a	A	D	F	704
	b	B	C	E	
	23a	C	E	D	705
	b	B	A	F	
	24a	C	D	A	706
	b	E	F	B	
5/16	25a	A	B	C	707
	b	F	D	E	
	26a	C	E	F	701
	b	D	A	B	
	27a	F	C	E	702
	b	D	B	A	
5/17	28a	B	E	D	703
	b	F	A	C	
	29a	C	F	E	704
	b	A	D	B	
	30a	E	C	A	705
	b	F	D	B	
5/20	31a	F	C	B	706
	b	D	A	E	
	32a	F	B	D	707
	b	A	C	E	
	33a	E	D	F	701
	b	B	A	C	
5/21	34a	C	F	E	702
	b	A	D	B	
	35a	E	A	C	703
	b	F	B	D	
	36a	C	F	B	704
	b	D	E	A	

a = 1 hour
b = 1 hour

APPENDIX C

NAVIGATIONAL ERROR MODEL

NAVIGATIONAL ERROR MODEL

A navigational model was developed to enable the realistic representation of computer-generated aircraft on the controller display. Aircraft flying the approach segment of a flight typically deviate a nominal amount from the Instrument Landing System (ILS) course heading, as seen in the Memphis and Chicago surveys (Buckanin and Biedrzycki, 1987; Timoteo and Thomas, 1989). Navigational error, the deviations from the ILS course heading, has a number of sources including avionics error, ILS signal error, weather, and ordinary pilot performance. An accepted amount of navigational error exists with current navigational systems. The model developed for this simulation dynamically generates a unique flightpath for each computer-generated aircraft in the simulation.
In order to accurately display navigational error two criteria must be met in the design of the model:

1. Flight paths of individual aircraft should look reasonable to the controllers; i.e., deviations from the localizer centerline should be typical of aircraft as they fly along the ILS approach.

2. Aggregate errors should reflect the accuracy typical of aircraft in the traffic sample, (e.g., the data collected at Chicago O'Hare).

Although pilots attempt to follow the ILS precisely, they often fly a course which is nearly asymptotic to the ILS course heading, and they intercept the ILS near the threshold. To model this part of the navigational error, a concept of pseudoroutes was implemented. A pseudoroute is a straight line originating at the center of the runway threshold and extending outward beyond 20 nmi. Pseudoroutes are offset from the ILS localizer centerline based upon a normal distribution with a mean of 0 degrees and a standard deviation of 0.25 degrees. A deviation of 0.25 degrees equates to 26.5 ft per nmi.

There are also deviations from the asymptotic course, or pseudoroute, described above. The deviations from the pseudoroute are usually sinusoidal in behavior (i.e., the error is a side to side motion about the average). The size of this deviation also decreases as the aircraft approaches the threshold. To model this part of the navigational error a fan is defined. The fan width (angle) is randomly assigned with a mean of 0 degrees and a standard deviation of 0.24 degrees. The fan width is capped at 1.8 degrees. The fan begins at the threshold and is bisected by the pseudoroute.

As aircraft fly the ILS approach course, they fly between the fan boundaries. If the aircraft intercepts the fan boundary, it will execute a turn at half rate (1.5 degrees per second) which will

direct them towards the opposite fan boundary. This was repeated throughout the approach until landing or given a heading change.

To facilitate the understanding of the navigational error model, an example is given in figure C-1. Initially, aircraft will make a 30- degree track intercept of the localizer approximately 17 nmi from the threshold. All aircraft turn-on to intercept their randomly assigned pseudoroute (0.7 degree offset = 179.3 heading in the example). The aircraft pass through the assigned pseudoroute centerline and approach the randomly assigned fan boundary (0.25 degree offset in the example). At the boundary, the aircraft will commence a one-half standard rate turn (1.5 degrees per second) back towards the pseudoroute on a heading equivalent to the pseudoroute heading minus 10 times the fan width (179.3 - 10 * 0.25 = 176.8 degrees). The process will repeat until the aircraft reaches the runway threshold and lands. If the controller requests an aircraft to return to the localizer, the pseudoroute offset was reduced 20 percent.

This navigational error model produces navigational error distributions that correspond closely with those found in the Chicago data, and it provides visually realistic targets to the controllers.
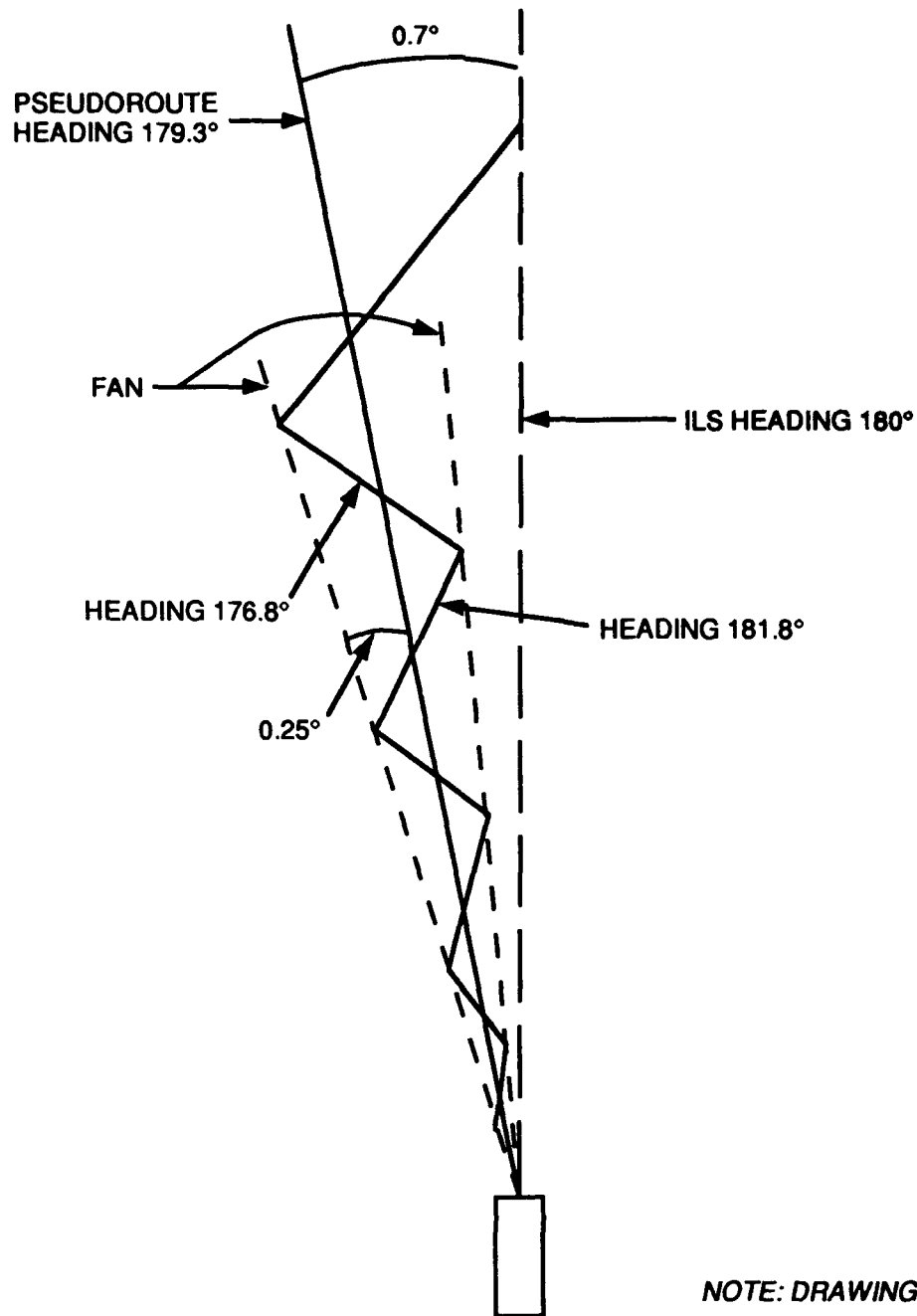
FIGURE C-1. EXAMPLE OF NAVIGATIONAL ERROR MODEL

APPENDIX D

CONTROLLER REPORT

Executive Summary

Monitoring of triple parallel ILS approaches to runways, with evenly aligned thresholds and runway centerlines spaced 3,400 ft apart, can be safely monitored by air traffic controllers using the Sony 20 x 20 high resolution color monitors and associated alert features with a 2.4 second radar update rate.

Monitoring of dual and triple parallel ILS approaches to runways, with evenly aligned thresholds and runway centerlines spaced by 4,300 ft, can be safely monitored by air traffic controllers using the Sony 20 x 20 high resolution color monitors and associated alert features with a 4.8 second radar rate.

D-1

Introduction

On May 5, 1991, a team of six air traffic control specialists participated in a simulation study. The study was a real time air traffic control simulation known as, ATC SIMULATION OF TRIPLE SIMULTANEOUS PARALLEL ILS APPROACHES WITH RUNWAYS SPACED 3,400 FT APART (TRIPLES) and 4,300 FT APART (DUALS AND TRIPLES) USING COLOR DISPLAYS, Phases V.c and V.a.1.

The equipment used for this test was Airport Surveillance Radar (ASR)-9 with Sony 20 x 20 high resolution color monitors. The Sony displays incorporated computer generated voice and color coded data blocks. The No Transgression Zone (NTZ), the runway, the runway extended centerlines, the distances from centerline reference lines, and the obstacle reference areas were defined by different colors.

Phase V.c evaluated triple parallel three runways with a 3400 centerline separation and a radar update rate of 2.4 seconds. Phase V.a.1 evaluated dual and triple parallel runways spaced at 4300 ft, with a 4.8 second radar update rate.

Aircraft simulators were used to provide realistic pilot and aircraft characteristics. These simulators included the NASA Ames facility, Moffett Field, CA; Mike Monroney Aeronautical Center, Oklahoma City, OK; Delta Air Lines, Inc., Atlanta, GA; AVIA Inc., Costa Mesa, CA; and the FAA Technical Center, Atlantic City, NJ; and a pseudo-pilot aircraft generator.

The objective for the controllers during the simulation was to detect unsafe aircraft flight path deviations (blunders) and to issue instructions in sufficient time to allow resolution between the blundering and non-blundering aircraft.

Analysis

Phases V.c and V.a.1 of this simulation used an airport configuration of three evenly aligned thresholds with a runway centerline separation of 3,400 ft for Phase V.c and 4,300 ft for Phase V.a.1. The simulation used a radar model based on the ASR-9. The radar information was displayed on a Sony 20 x 20 high resolution monitor. The monitor was equipped with a voice alert warning system and color coded data blocks. Its purpose was to warn the final monitor controller when an aircraft progressed near or penetrated the NTZ.

The display scale on the monitors could be expanded in the area between the runways to provide the controller with an improved capability to detect aircraft movement away from the extended runway centerline. The controllers during this simulation were directed not to change this parameter. Although we were able to observe blundering aircraft, and the alert system was an aid in quickly identifying the blundering aircraft, we believe the selection of a wider scale on the monitor would have better served us in resolving some of the blunders with close miss distances.

During Phase V.c, Flight Technical Error (FTE) and navigational error were more prevalent during the final course intercept phase. FAAH 7110.65F, para. 5-126, d, SIMULTANEOUS ILS/MLS APPROACHES requires a clearance for the aircraft to descend to the appropriate glideslope/glidepath intercept altitude to provide a period of

level flight to dissipate excess speed at least one mile of level flight prior to the approach course intercept. This is the arrival/final controller's responsibility. During the course of this simulation, there were several times when the final monitor controller had to issue instructions to correct aircraft to rejoin the appropriate localizer. Some targets assigned to runway 18C were over or outside the 18L or 18R centerlines. Aircraft assigned to runway 18L were over or outside the 18C or 18R centerlines; and aircraft assigned to runway 18R were over or outside the 18C or 18L centerlines. In order to maintain approved separation some of the aircraft had to maintain their altitudes until they were established on their respective localizer. This condition happened often and therefore interfered with the local controller's use of the frequency. This situation was not as prevalent during Phase V.a.1, perhaps because of the wider space between the runways and the slower radar update rate.

Departure Tags

The departure data blocks were difficult to differentiate from the arrival data blocks. The departure data blocks were the same color and contained the same information as the arrival data blocks. The departure data blocks should have a fix in the scratch pad, or they should be a different color.

Outer Marker Reports

This simulation required the pseudo and the simulator pilots to make outer marker reports. In a radar environment there is no requirement for pilots to make outer marker reports. FAAH 7110.65 makes no requirement for outer marker reports except in a non-radar environment. The Airman Information's Manual (AIM), para. 342, 2.a states that only in a non-radar environment are outer marker reports compulsory. We were monitoring triple parallel ILS approaches, therefore outer marker reports were redundant. This requirement raised the question, if a pilot does not report the outer marker, is the controller required to verify the aircraft's position? This was a needless information exchange on an already crowded local frequency.

Predictor Lines

At the controller's request, the predictor lines in Phase V.a.1 were changed to add a fifteen and a twenty second predictor. Previously the highest selectable value was ten seconds. However, the alert parameters were not changed to match the selectable value. The alert system was set at fifteen seconds, no matter what value of predictor line was selected from the menu. For a five, ten, fifteen, or twenty second predictor line, the alarm parameter was set at fifteen seconds. The alarm parameter should match the selected predictor line.

Alpha-Numerics

Some letters, such as "E" and "F", are difficult to differentiate in the data block. Line 1 of the data block was too close to line 2. These characters were also difficult to discern against the map line. These letters were often misinterpreted and caused misidentification of some aircraft. A solution to this is to offset line 1 higher than line 2.

BREAK

A requirement for this simulation was to test the effectiveness of the word "BREAK" in place of the word "IMMEDIATELY", when issuing urgent heading instructions during a blunder situation. We had to use the word "BREAK" followed by the direction of turn and compass heading. For example, "United 767, BREAK right heading 270, climb and maintain 4,000."

The suggestion for the term "BREAK" originated from Airline Pilot's Association (ALPA) representatives. They feel the term "IMMEDIATELY" has become overused as a normal part of ATC instructions and has lost its impact. The controllers position is that the term "BREAK" already has one definition. Presently "break" is defined as a phase of flight in the recovery of military aircraft to the VFR pattern. Break is that point where the first 180 degree turn is made from initial in the overhead pattern. Therefore, the use of "BREAK" in simultaneous approaches is

uncharacteristic for its normal definition in controller phraseology.

Blunders are a rare event and, in all likelihood, one which most controllers will never witness. In this respect, it is unreasonable to make both pilots and controllers responsible to apply the word "BREAK" in an actual blunder. The controller will likely use the word "IMMEDIATELY" to request immediate pilot compliance with a control request.

Altitude Assignment

In this simulation, the controller was required to issue an altitude assignment with the "BREAK" instruction. This requirement removed the discretion from the controller to decide what evasive maneuver (turn, climb or descend) will provide the quickest resolution from the blundering aircraft. When the required procedures were applied, we often had to repeat a part, or all of the breakout instruction to the pilot. At this point, any delay on controller or pilot reaction became time critical. Whatever instruction the controller did not give (turn, climb or descend) can always be followed by the other. It is our position that giving one instruction at a time is faster, safer and less prone to errors. In any event the pilot has the MDA, or MSA for altitude reference.

Blundering Aircraft

Most of the NORDO blundering aircraft seemed to descend to the surface. It may be reasonable to think some aircraft are having difficulty maintaining level flight and NORDO, but not all of the blunders. Some of the blundering aircraft should maintain the MDA, MSA or execute a missed approach. This is not a difficult separation problem, because it would be handled like any other missed approach, go-around or breakout aircraft.

Communications

Several times during the simulation controllers had to repeat instructions 3 to 5 times before a response was received from pilots. The delay in response from the pilots reduced the miss distance between blunders and vectored aircraft. Sometimes the radio frequencies were weak, but a part of the problem may be flight crews were not used to hearing the call sign assigned for their particular run. For example, the simulator crew may have been an Delta airlines crew flying under a American or United call sign.

The controller team had to staff the tower local function when they were not on the final monitor position. This was to raise the sense of realism for pilots by the voices of controllers from the field.

Simulator Performance

During this simulation it became evident that many pilots have a different definition of the word "immediately". The word "immediately" was used when a climb or descend clearance was issued. Some crews would climb 3,000 feet in 30 seconds. Others would either show a Mode C readout of no change to a few hundred feet. The slower performance from the pilots is not a desirable response in a blunder event. The disparity of performance among flight crews must be addressed in future simulations and training.
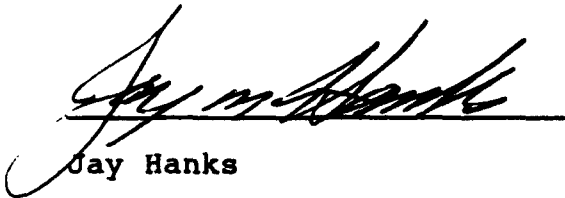
Conclusion

Phase V.c and Phase V.a.1, triple parallel simultaneous ILS approaches at 3,400 ft with a 2.4 second radar update rate and 4,300 ft duals and triples with 4.8 second radar update rate using the Sony high resolution 20 x 20 color monitors and alert system are acceptable and safe operations.

Recommendations

1. The word "BREAK" should not be used as an attention-getter for a breakout in an actual blunder situation for the reasons outlined in the Analysis section of this report.

2. An education process must be reemphasized for controllers and pilots the use of the word "IMMEDIATE". An education program must be developed for pilots on the use of the word "IMMEDIATELY". Many pilots demonstrated their different understandings of "IMMEDIATELY" in their responses to controller instructions.

3. The controller should be allowed the discretion to expand the X-axis on the Sony monitor. The X-axis can be expanded to allow the controller to more quickly identify a blunder.

4. Another controller is needed to help with relief periods if two hour sessions are the norm in the simulations.

5. The controller should have the option of using the Dec-Talk through the headset or the speaker.

Signatory

(signature)

Jay Hanks

Atlanta ATCT

(signature)
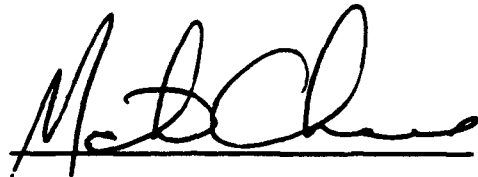
Charles Maxwell

Pittsburgh ATCT

(signature)

Patrick Karsten

Minneapolis ATCT

(signature)
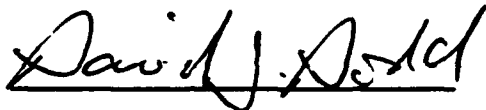
Michael Chance

Denver TRACON

(signature)

Harold R. Anderson

Dallas/Ft. Worth TRACON

(signature)

David Dodd

Sacramento TRACON

APPENDIX E

POST-RUN CONTROLLER QUESTIONNAIRE

POST RUN CONTROLLER QUESTIONNAIRE

PHASE: V.c   or   V.a.1

PARTICIPANT CODE_____   DATE_____

PARTNER'S CODE___ ___ ____   TIME_____

RUN NUMBER_____   RUNWAY_____

PLEASE FILL OUT THIS BRIEF QUESTIONNAIRE ON THE RUN YOU HAVE <u>JUST</u> <u>COMPLETED</u>.

---

1. Rate your level of activity required during the past hour.

   1   2   3   4   5   6   7
   Minimal   Moderate   Intense

---

2. How well were you able to control the traffic using the high resolution displays?

   1   2   3   4   5   6   7
   Minimal   Moderate   Intense

---

3. Rate the level of stress experienced during the past hour.

   1   2   3   4   5   6   7
   Minimal   Moderate   Intense

---

4. In each of the approach blunders presented, do you think that you had adequate time to break-out an endangered aircraft?

   Yes___   No___

   If "NO", please explain:

5. Please describe any unusual occurrences from the last hour. Please note any unusually long delays or incorrect pilot responses.

6. Please rate the session you have just completed. Choose the one response that best describes your workload level based upon the mental effort and the slant range miss distances (SRMD) between blundering and nonblundering aircraft.

Large slant range miss distances (SRMD) are greater than 1 nm, adequate SRMD are greater than 500 ft but less than 1 nm, close conflicts are less than 500 ft.

1. **Minimal** mental effort is required and **large** SRMD are easily attainable.

2. **Low** mental effort is required and **adequate** SRMD are attainable.

3. **Acceptable** mental effort is required to maintain **adequate** SRMD.

4. **Moderately high** mental effort is required to maintain **adequate** SRMD.

5. **High** mental effort is required to maintain **adequate** SRMD.

6. **Maximum** mental effort is required to maintain **adequate** SRMD.

7. **Maximum** mental effort is required to keep the number of **close conflicts to a minimum.**

8. **Maximum** mental effort is required to keep the number of **close conflicts to a moderate level.**

9. **Intense** mental effort is required and **numerous close conflicts** occur.

10. Close conflicts **cannot** be prevented.

APPENDIX F

POST-SIMULATION CONTROLLER QUESTIONNAIRE

POST SIMULATION CONTROLLER QUESTIONNAIRE

1. Did you have all the information needed to perform the Monitor Controller task?

   Yes___ No___

   If your answer is "NO", please comment:

---

2. Adequate training time was provided to become familiar with the display before beginning the Simulation.

   Yes___ No___

   If your answer is "NO", please comment:

---

3. Independent IFR approaches to runways separated by 3400 ft can be safely conducted.

   1   2   3   4   5   6   7
   Disagree   Agree

---

4. Independent IFR approaches to runways separated by 4300 ft can be safely conducted.

   1   2   3   4   5   6   7
   Disagree   Agree

5. Would the conditions of this past hour (volume of traffic, procedures, geography, separation minimum) be workable at your facility?

        1   2   3   4   5   6   7
        Strongly   Strongly
        Agree   Disagree

---

6. Would you prefer victim aircraft to turn red in lieu of victim aircraft turning yellow?

        Yes___ No___

---

7. Do you feel adequate information was provided in the data block?

        Yes___ No___

        If your answer is "NO", please comment:

---

8. Do you feel your level of stress was higher during the triple approach operation vs. the dual?

        Yes___ No___

        If your answer is "YES", please comment:

---

9. Except for deliberately introduced incidents, how realistic was this traffic (aircraft types, density)?

        1   2   3   4   5   6   7
        Not   Very
        Realistic   Realistic

10. Did the simulation (both audio and visual) provide a realistic portrayal of each approach blunder?

1   2   3   4   5   6   7
Not   Very
Realistic   Realistic

---

11. Describe to what extent, if any, the different radar update rates effected your ability to control traffic.

---

12. Did you and your partners establish any strategy or agreement regarding inter-controller coordination? If your answer is yes, please describe briefly below what you decided to do even if the arrangement was unspoken. Be specific and include controller letter codes.

---

13. Please describe any items in the simulation which you believe were not realistic or whose realism could have been improved upon:

APPENDIX G

PILOT QUESTIONNAIRE

PILOT QUESTIONNAIRE

SIMULATION OF SIMULTANEOUS APPROACHES

PHASE: V.c or V.a.1

DATE: _____   RUN: _____

PILOT ID: _____   SAMPLE: _____

SITE: _____   INDEX: _____

---

1. RATE THE LEVEL OF WORKLOAD REQUIRED DURING THE PAST APPROACH.

   1   2   3   4   5   6   7   8   9   10

MINIMAL   MODERATE   INTENSE

---

2. When the controller issued instructions for a "break-out" maneuver, were you able to follow the instructions immediately? Yes ___ No ___.

If No, Explain. _____
_____
_____
_____
_____
_____

3. Describe any unusual or abnormal occurrences during the past blunder. Please include aircraft ID's and approximate time if possible. _____
_____
_____
_____
_____
_____
_____
_____

4. Additional Comments?   _____
_____
_____
_____
_____
_____
_____

APPENDIX H

FLIGHTCREW OPINION SURVEY

FLIGHTCREW OPINION SURVEY

Answer each question to the best of   1- strongly disagree
your ability using the scoring scheme   2- disagree
shown to the right. You are invited   3- don't know
to provide additional comment on any   4- agree
item in the spaced provided at the   5- strongly agree
end of the survey form. Please
reference the item number.

1.0 SURVEY ITEMS

1.1 Current parallel runway procedures   1 2 3 4 5
require 1000 feet of vertical separation
at the localizer turn-on for separation.
In the event one (or both) aircraft
overshoot the localizer, 1000 feet of vertical
separation would provide an acceptable safety
margin provided aircraft maintain their
assigned altitude until established on the
localizer course.

1.2 Due to the importance of not straying   1 2 3 4 5
into the NTZ, all closely spaced parallel
approaches should be conducted with a
coupled autopilot.

1.3 If an aircraft penetrates the NTZ while   1 2 3 4 5
another aircraft is conducting a
simultaneous parallel approach, the
monitor controller will immediately
direct the threatened aircraft off
its approach course to a heading/altitude
that will prevent a collision. To
emphasize the importance of a quick
response from the threatened aircraft,
special phraseology should be used for
the breakout maneuver.

1.4 Additional pilot training/currency   1 2 3 4 5
requirements (e.g. category 2 and 3 ILS
requirements) are necessary to qualify
pilots for simultaneous independent
approaches to parallel runways separated
by 5000 ft.

2.0   GENERAL COMMENTS.

2.1 Please provide any suggestions that you think would
enable the operation of multiple simultaneous parallel
ILS approaches to be a safe and effective procedure.

2.2 Please provide any relevant feedback about the current
simulation.

APPENDIX I

OPERATIONAL ASSESSMENT

OPERATIONAL ASSESSMENT

The Operational Assessment provides a comprehensive review of all conflicts that resulted in a Closest Point of Approach (CPA) of less than 500 ft. The review examined data from video and audio recordings, controller questionnaires, technical observer logs, aircraft position plots and data records, and pilot surveys.

The Multiple Parallel Technical Work Group (TWG) reviewed the blunder data and determined whether mitigating circumstances may have contributed to the severity of the blunder. A decision was then made concerning the inclusion of the blunder into the database for analysis. There was one test criterion violation (TCV) reviewed in the Operational Assessment. The review indicated that the TCV was valid.

The factors that contributed to the severity of the outcome were the pilots of both the blundering aircraft and the evading aircraft. The pilot of the blundering aircraft did not respond to controller instructions, and the pilot of the evading aircraft was slow in implementing the controller instructions. A graphic plot and computer generated data are included to aid the reader in reviewing the blunder.

The graphic plot represents the aircraft's lateral movement along the localizer. As shown in figure I-1, the localizer is indicated by vertical dashed lines and the aircraft tracks are solid lines that follow and eventually deviate from the localizer lines. The horizontal (x) and vertical (y) axes are marked in nautical miles from an imaginary origin. Simulation time (recorded along the aircraft tracks) is marked in 10-second increments. The aircraft identification is indicated at the beginning of each track.

An example of the digital data associated with the graphic plot is provided in table I-1. The data include increment time (from the plot), simulation time (seconds), x coordinate, y coordinate, altitude, ground speed, heading, track status (1000 = Off-Flight-Plan on Vectors, 1060 = Flying ILS Approach, 1061 = Homing to ILS Approach, 1068 = Deviating from ILS Approach), and the distance the aircraft traveled once the plot was initiated.

The example shown in figure I-1 began with FDX968. The aircraft was inbound on the center runway when it blundered 30 degrees to the right at simulation time 7029. The data for this blunder are shown in table I-1. At simulation time 7057, the controller issued a vector change for N176ZN, on the right runway (18R), to turn right heading 270 and descend to 2000 ft. The CPA attained by these aircraft was 174 ft.

Both aircraft were computer-generated aircraft. The blundering aircraft continued to descend during the blunder.

CONCLUSIONS.

Based upon the review of the blunders and their knowledge of air traffic operations, the TWG indicated that the Final Monitor Aids (FMA's) enabled controllers to successfully resolve 99.7 percent of the worst case blunders. The advanced controller display system enabled controllers to detect blunders quicker and initiate corrective commands.
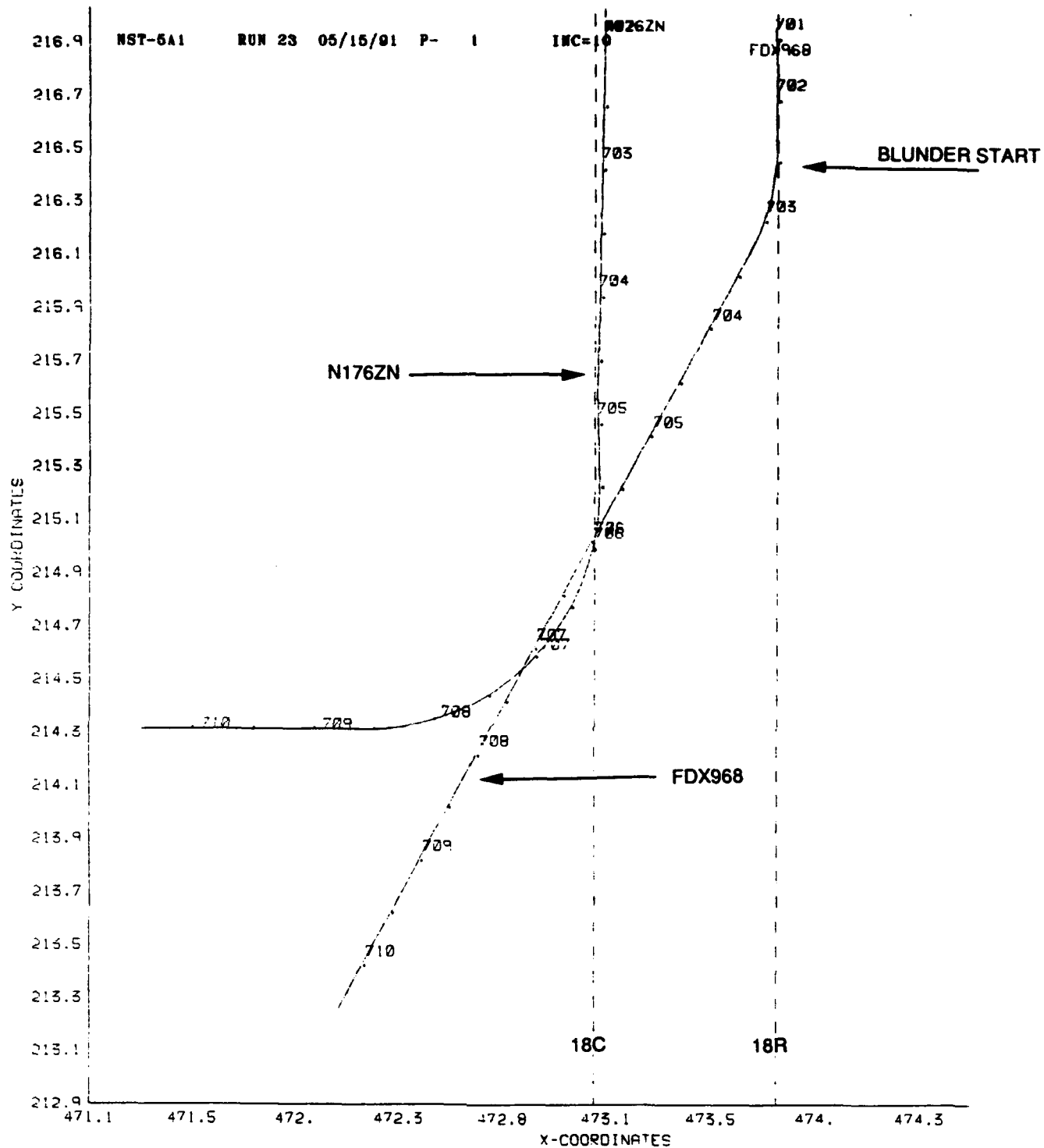
FIGURE I-1. GRAPHIC PLOT OF TCV

TABLE I-1.   DIGITAL DATA FOR TCV

FLIGHT: FDX968

INC	TIME	X	Y	ALT	TSPD	HDG	TRACK	DISTANCE
701	7014	473.843	217.051	3855	167	180	1060	.00
702	7019	473.846	216.820	3777	166	180	1060	.23
703	7029	473.807	216.363	3620	166	193	1000	.69
704	7039	473.601	215.953	3463	166	208	1000	1.15
705	7049	473.379	215.551	3306	165	208	1000	1.61
706	7059	473.157	215.151	3149	165	208	1000	2.07
707	7069	472.936	214.751	2992	164	208	1000	2.53
708	7079	472.716	214.352	2835	164	208	1000	2.98
709	7089	472.497	213.955	2678	164	208	1000	3.43
710	7099	472.277	213.558	2521	163	208	1000	3.89

FLIGHT: N176ZN

INC	TIME	X	Y	ALT	TSPD	HDG	TRACK	DISTANCE
701	7014	473.192	217.280	3760	173	179	1060	.00
702	7019	473.189	217.040	3683	173	181	1060	.24
703	7029	473.179	216.560	3528	173	181	1060	.72
704	7039	473.170	216.082	3373	172	181	1060	1.20
705	7049	473.164	215.604	3219	172	179	1060	1.68
706	7059	473.153	215.130	3029	171	188	1000	2.15
707	7069	472.949	214.716	2696	171	218	1000	2.62
708	7079	472.567	214.460	2363	170	248	1000	3.08
709	7089	472.109	214.413	2035	169	270	1000	3.55
710	7099	471.639	214.413	2000	169	270	1000	4.02

APPENDIX J

TECHNICAL OBSERVERS REPORT

TECHNICAL OBSERVERS REPORT

This report is the consensus of the Technical Observers Group concerning the Phase V.c and V.a.1 simulation. It contains general opinions and specific conclusions regarding controller performance and simulation procedure overall.

The Group observed each of the controllers performing duties at the final monitor position. We had the opportunity to evaluate each controller's reaction to the blunders, the realism of each scenario, and the reactions of the simulator and the pseudo pilots to the instructions issued by the controllers.

These phases of the simulation were built on a worse case scenario that would rarely, if ever, be seen in the field. The controllers' ability to resolve the problems created by blundering aircraft was plagued by incorrect pilot actions, slow response times and missed instructions by the pilots. However, these discrepancies did not hinder the controllers' ability to safely separate the aircraft. The Group believes that the test proved the controllers' and pilots' ability to avoid blundering aircraft even under these conditions.

The FTE that affected Phases V.b.1 and V.b.2 of the simulation was not a factor in Phases V.c and V.a.1 of the simulation.

The word "break" was used by the controllers in these phases of the simulation; i.e., "break right/left" instead of "turn right/left immediately". This change was made, as requested by a pilot's group, to give pilots the ability to recognize when a breakout instruction was given as a result of a blundering aircraft. It is our opinion that the use of the word "break" is not an improvement to existing phraseology, and would do nothing to enhance safety. The term "immediate" is universally understood by both pilots and controllers, especially during airborne operations.
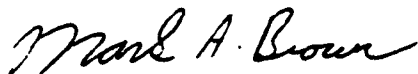
The ability to immediately communicate with an aircraft in order to issue breakout instructions was occasionally delayed when another aircraft was transmitting to the tower on the same frequency. To correct this problem, the Group recommends that voice capability be provided on all ILS localizers serving runways spaced less than 4300 feet, if simultaneous parallel approaches are authorized.

It was suggested during the simulations that complete ARTS interface is necessary before the Sony monitors are used in the field. The Group disagrees with this observation. We recommend that automated handoffs to feeder/final positions be programmed into the ARTS system as an interim measure.

Conclusion

It is the Group's opinion that this simulation proved that, with the use of Sony high resolution color displays with controller alerts, a safe, efficient and effective operation can be achieved as follows:

- with back to back radar with a 2.4 second update - dual/triple simultaneous approaches to runways spaced 3400 feet apart.

- with existing radar with 4.8 second update - dual/triple simultaneous approaches to runways spaced 4300 feet apart.

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